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R. F. REMOTE SET INFORMATION LINK STUDY

M. D. Egtvedt, et al

General Electric Company

Prepared for:

Picatinny Arsenal

April 1975
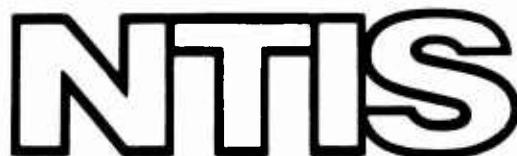
REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) R.F. Remote Set Information Link Study		**5. TYPE OF REPORT & PERIOD COVERED** Final Report June 1974 - March 1975
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) M. D. Egtvedt J. A. Kinzel R. T. Ziemba		**8. CONTRACT OR GRANT NUMBER(s)**
9. PERFORMING ORGANIZATION NAME AND ADDRESS General Electric Company Armament Systems Department Burlington, Vermont		**10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS**
11. CONTROLLING OFFICE NAME AND ADDRESS		**12. REPORT DATE** April 1975
		13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		**15. SECURITY CLASS. (of this report)** Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

DISTRIBUTION STATEMENT A

Approved for public release;
Distribution Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Remote Set Fuzing   Rocket Fuzing
Electronic Fuzing
RF Fuzing Data Link
Multi-option Fuzing

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes the design, development and test of an rf data link system whose function is to remotely set an electronic time fuze (2.75" rocket) to one of three options following rocket launch.

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FINAL REPORT

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April 1975

Prepared for

PICATINNY ARSENAL

Ammunition Development and Engineering Directorate

Fuze Development and Engineering Division

Dover, New Jersey 07801

Contract No. DAAA-21-74-C-0474

DA Project No. 1W662603A004 Task 5   AMCNS No. 662603.12.22305

GENERAL ELECTRIC COMPANY

Armament Systems Department

Burlington, Vermont

and

Electronics Laboratory

Syracuse, New York
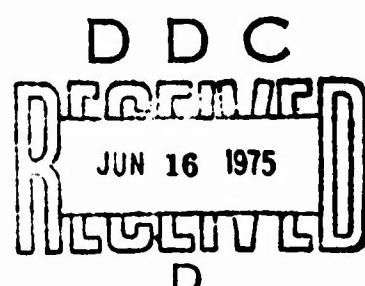
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FOREWORD

This report summarizes the work performed by the General Electric Company under Contract No. DAAA21-74-C-0474 for the Ammunition Directorate at Picatinny Arsenal, Dover, New Jersey. The period of the contract was from June 1974 through March 1975.

The initial effort of this program was directed to the study of technological trade-offs relating to current and improved receiver design, multi-option data link capability and transmitter modifications necessary to implement these system improvements. The program was subsequently amended to include the fabrication of 15 sets of fuze hardware whose function was to demonstrate the design implementation resulting from the study effort.

The General Electric Company gratefully acknowledges the efforts of Mr. William Quine, Picatinny Arsenal Technical Director, for his valuable contributions, advice and consultation throughout the program. In addition, we wish to express our appreciation for the technical consultation and support provided by Mr. Henry Hagedorn of Picatinny Arsenal during the course of this program. Also we acknowledge the use of services and facilities provided by Picatinny Arsenal in support of the range testing at Camp Edwards, Massachusetts.

This technical report contains neither classified nor company proprietary information.

ABSTRACT

This technical report summarizes work performed in the study, design, fabrication and test of a remote settable, multi-option fuze for use in 2.75" FFAR munitions.

The principal objective of this contract effort was to conduct technology studies of an rf data link system consisting of a low powered, x-band pulsed transmitter (helicopter fuselage mount) communicating with 2.75" FFAR pod-mounted munitions. This improved communication link was to provide both time setting and fuzing mode information to the rockets immediately following rocket launch.

The findings of the system study relating to the data link communication technique were subsequently reduced to hardware in the form of 15 rocket fuzes and a modified data link transmitter capable of communicating the commanded fuzing information to the in-flight rockets.

Two major hardware advances made during the course of this program deserve note. The first was the use of an improved low-g setback generator to provide power to the rocket fuzes. These induction generators produced about ½ million ergs of energy within 20 milliseconds from rocket first motion. This fast and repeatable rise-time characteristic is a required feature in the development of any accurate, electronic time fuze intended for ordnance applications.

The second significant hardware development of this program was the design and subsequent implementation of a stable, quartz crystal tuning fork oscillator which served as a fuze time base generator. The major design feature of this oscillator was its fast start time (approximately 10 milliseconds) from the power-on signal. This design characteristic represents a significant improvement over the 200 to 500 milliseconds start-up time for crystal tuning fork oscillators of a more conventional design. It is the fast, repeatable start-up time of this improved oscillator which makes its application to ordnance time fuzes practical.

Fifteen sets of fuze hardware, together with a data link transmitter, were delivered (in place) to Picatinny Arsenal in December of 1974 for subsequent test and evaluation at a military test facility.

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INTRODUCTION

Since early in 1970, the General Electric Company sponsored by the Ammunition Engineering Directorate at Picatinny Arsenal has pursued the development of remote set fuzing techniques for a variety of ammunition systems including indirect fire artillery, tank-fired cannons and air-to-ground rockets. The effort supported by this current contract represents a continuation of this development activity as related to its implementation in 2.75" Folded Fin Aerial Rocket (FFAR) systems. A previous contract effort (DAAA21-73-C-0764) established feasibility of the rf remote fuzing technique for such rocket systems.

Three significant technical advances were established as goals for this present program, all of which have been realized and incorporated into the deliverable hardware. They are:

1. Implementation of a multi-option fuzing capability via an rf data link between the launch platform and the rocket fuze.

2. Use of a quartz crystal timing fork oscillator as the fuze time base generator.

3. Use of a low-g setback generator for use as the fuze power source.

Though much additional component development work has yet to be accomplished before a remote set fuzing system having these features can be fielded, the basic elements of such a design have now been demonstrated.

The technical effort which led to this development is described in the sections of this report which follow.

SECTION II

PROGRAM OBJECTIVES AND GUIDANCE

The principal objectives of this program were (1) to conduct specific studies on a remote settable information link concept developed under previous related contracts and (2) to refine the design of the data link transmitter, receiver and fuze logic circuits. This program was subsequently amended to include the fabrication of 15 sets of demonstration hardware whose design would incorporate the features and improvements identified during the course of the study phase of this effort.

The specific tasks to be performed within the study effort were:

1.   Fuze Receiver Redesign

The rocket fuze receiver as defined by GE drawings SK56157-D155-9 and SK56457-D155-4 operates at approximately 12 volts, consuming a significant amount of power during the period in which it is called upon to operate. This power drain places a severe penalty on the size and weight of the fuze power supply necessary to sustain this load. In fact, it consumes a major portion of the entire energy reserve within the fuze even though it is only "on" a small fraction of the total time that the fuze operates within the rocket flight trajectory.

An effort would be made, through appropriate receiver circuit modifications, to reduce the power drain attributal to the fuze receiver. One significant step toward this goal would be through a basic change in the data link operation. A "gated fuze" receiver approach would be investigated which would reduce the period during which the receiver is normally "on" from 300 milliseconds to about 10 milliseconds. This 30:1 power-on time reduction represents about a 50:1 power saving from the source supply which is an unreplenished charged capacitor bank. In addition, circuit design changes would be investigated with the intent of further reducing the power drain on the stored energy bank during this shortened period.

2.   Fuze Logic Circuit Design

The remote set fuzing technique, developed during the course of previous contract work in this area, provided a single remote command to a projectile fuze. This command was, in effect, information to detonate the projectile warhead after a given time-of-flight of the round into its trajectory. New fuzing logic which would provide for a number of additional

command functions to the fuze would be studied as to its adaptability to this remote set application. Incorporation of this feature into a remote set fuze would provide the gunner with such optional fuze function features as Superquick, Delay Function, Canopy Delay, Bunker Penetration, Time, and Proximity. These commanded functions would be set into the fuze, remotely, after the rocket has left the launcher.

Studies would be undertaken to determine the manner of best incorporating this multi-option feature into the fuze circuits and the manner in which commands for these function selections would be transmitted to the fuze via the information data link.

3.   Data Link Transmitter Redesign

The existing data link transmitter is presently mechanized to transmit a single, narrow burst of data to the fuze at some time between T_0 (muzzle exit) and a time (T_1) some 300 milliseconds following T_0. During this period, the fuze receiver is "opened" and "listening" for setting information.

Alternate communication techniques would be explored which would reduce the period during which the fuze receiver is "opened" and thus vulnerable to electronic countermeasures (ECM). Changes in the transmitter design would reflect these design improvements. In addition, coded modulation techniques would be explored which would provide for the implementation of a multi-option fuzing selection. It is desirable that a minimum number of hardware changes to the existing transmitter design be required to implement these additional setting options.

As a part of this study task, consideration would be given as to (1) the flight dynamics of the 2.75" rockets and the helicopter launch platform, and (2) the interrelationship between placement of the transmit antenna, its pattern and power out, and the pattern sensitivity of the in-flight fuze receivers.

These specific tasks, and pertinent additional information outlined in the Scope of Work issued for this contract, constitues the guidance for work under this program.

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SECTION III
TECHNICAL DISCUSSION

A. SYSTEM APPROACH

This study of an RF Remote Set Information Link was carried out using the 2.75-inch rocket system as the baseline system for its application. This introduced several significant and new requirements, as contrasted to artillery-based remote settable fuzing:

- Salvo firing capability, with firing intervals as close as 40 milliseconds.

- Multi-option command capability to fully utilize multi-mode warheads.

- Transmitter should be small, lightweight, and low-power for use in a helicopter.

- A setback generator power supply operable at the (relatively) low rocket acceleration levels.

Although initial concepts centered around communicating when the rocket was well in front of the helicopter, subsequent evaluation indicated several advantages to communicating within a few rocket lengths of the launcher:

- Lower transmitter (rf) power due to shorter path and smaller communication volume.

- Antenna aims to side instead of towards target, with possible implications for electronic counter-countermeasures, target warning, and avoiding radiation-seeking missiles. The disadvantage of requiring an antenna for each side is minor if a conformal antenna is used with the rf (solid state) source(s) mounted at each antenna.

- The signal propagation path is normal to the rocket plume, rather than near-axial, probably reducing the plume attenuation. (Test measurements of plume attenuation indicate that it is, at worst, 6 dB).

The salvo-firing requirement presented new data transmission problems in insuring that each missile received only one command. This was solved by using the "receiver window" message framing approach, which had earlier (DAAA21-72-C-0013) been analyzed (and

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bypassed) for the artillery application. The time signal is encoded in the pulse repetition frequency (PRF), which the fuze receiver measures by counting received pulses during an accurately timed gate or window. The transmitter may now be operated in a (quasi-) continuous fashion, at least to provide adequate time-coverage of all receiver windows.

Generating the receiver window requires a fuze time base which has a high accuracy when the logic generates the window; the time base must also have a predictable and repeatable start-up characteristic. The window accuracy directly affects the received command (PRF) accuracy. The start-up characteristic determines the time along the trajectory when the window occurs. This and the rocket trajectory (acceleration) variations determine the spatial variations of location of the window, which in turn defines the volumetric coverage required of the transmitter, and thus the antenna and rf power requirements.

Range tests (Section III F) were performed to obtain the necessary early trajectory data, using hot, cold, and ambient rocket motors with several payload weights. A new setback generator design was also tested and proven as it demonstrated a consistent nominal half million erg output, available after about four inches of rocket movement.

The fast-starting, high-accuracy time base was recognized as a key element; it also provided the greatest technical challenge. Picatinny Arsenal has, under another program, been performing some shock-survival testing of various low frequency crystals and subsequently made available some preliminary data indicating that a tuning-fork-shaped piezoelectric crystal manufactured by Statek Corporation should be given serious consideration in this application. Some crystal oscillators were obtained from Statek for testing; start-up times of 0.1 to > 1 second were observed. Mechanical shocking seemed to slightly reduce the delay; however temporary operation at sub-harmonic and harmonic frequencies was also noted. The observed variation in start-up time was so large as to destroy its usefulness as a time base. (One "fix" would use a burst transmission to reset the fuze circuits; this would require, in addition to fuze receiver complications, much greater transmitter power to reach the rocket after one-plus seconds.)

GE next obtained, from Picatinny and Statek, some crystals (only) mounted in TO-5 packages and built its own amplifier circuits following Statek application notes. Rather similar results were obtained. Two further design steps were then taken – increasing the loop gain and converting the circuit to a crystal-stabilized oscillator, as discussed in Section III C 3. As shown in Section III E, the oscillator start-up time variation as a result of these changes, was less than $\pm$ 2 milliseconds, except for one unit at +3 milliseconds. In addition, the window periods were consistently accurate.

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Having determined the rocket spatial position-vs-time characteristics, both nominal and the range of deviation, the transmission link was modeled based on the approximate dimensions of an AH-1G Huey Cobra carrying two XM-159 launcher pods on each stub wing (19 rockets/pods, 4 pods). With window time as the controllable parameter, the antenna pattern was optimized for minimum transmitter power. The details and results of this tradeoff study are covered in Section III A 1.

The remaining system requirement was to provide the multi-option select capability. Demonstration, in the absence of a suitable available multi-mode payload, required development of both transmission technique and a payload which could confirm proper operation. The Signature Warhead designed for this purpose is described in Section III D. Mode command was implemented by a binary pulse-width modulation (PWM) scheme (narrow and wide pulses), wherein the wide pulses serve to "frame" the message word, and the mode is encoded by the number of narrow pulses transmitted between the wide pulses. The mode-decoder in the fuze is relatively simple, and the PWM does not affect the time-delay setting.

Based on the preliminary tradeoff studies, it was determined that the RST-1 transmitter probably would be used, with a new transmitter control unit to provide the required signaling waveforms. The available rf power is marginal under worst-conditions, but is expected to be adequate for field demonstration of the concept.

1. SYSTEM TRADEOFF STUDIES

General

A system tradeoff study was performed on the remote set information link to determine the link's sensitivity to various parameters. The parameters considered included (1) time delay between reset pulse and window function, (2) transmit power, (3) transmit antenna gain pattern, (4) relative geometries of the transmit antenna location and the rocket receiver, (5) receive antenna gain pattern, (6) receiver sensitivities, (7) period of receive window, (8) time delay between first motion and the reset pulse, and (9) rocket motor temperature.

The figure of merit judged most applicable to this system was simply the rocket's minimum received power during the period when the rocket receive window was open. This criteria addresses itself to whether sufficient power is received by the rocket to reliably enable the transfer of information from the helicopter to the in-flight rockets.

The system geometry considered is illustrated in figure 1. Each helicopter wing supports two rocket pods, each pod containing 19 rockets. Since it is desirable to keep the transmit

antenna simple and inexpensive, it is assumed that the transmit antenna gain pattern is the same regardless of which rocket is fired. A rocket's location is confined to the track dimension which is the difference between the distance from the fuselage and the outer dimension of the far-out pod. It was estimated that this track extends from 1 to 4 feet from the helicopter fuselage. The position along the track, measured relative to the front of the helicopter, at the time the receive window is open, is a function of the rocket temperature, the time delay between first motion and the reset pulse, t_{fm-rp}, the hardwired time delay corresponding to the time between the reset pulse and the receive window opening, t_{rp-rw}, and the time duration of the receive window.
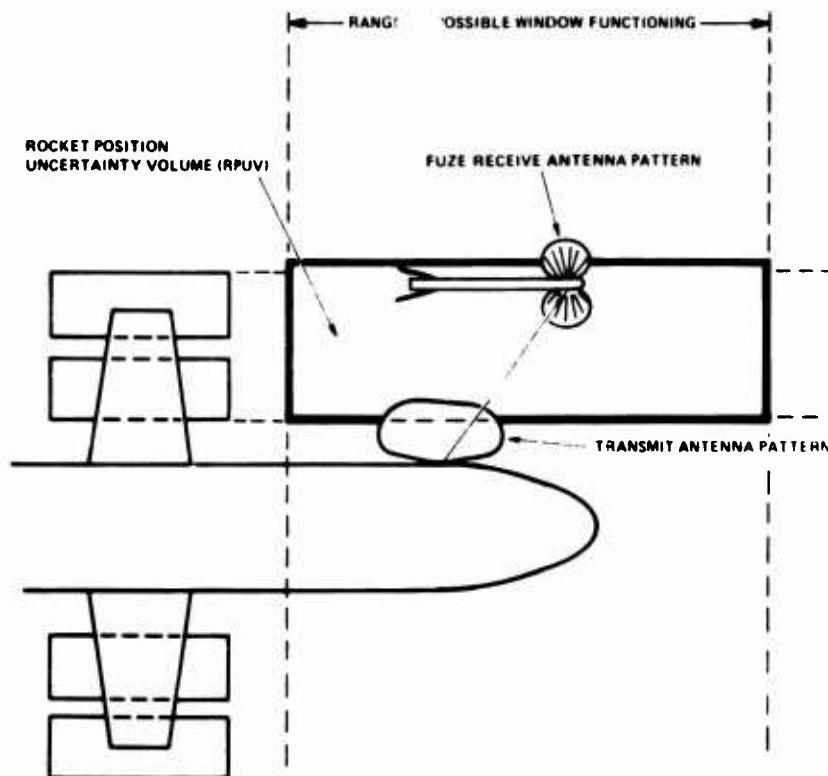
Figure 1. System Geometry

As illustrated later, there is a large uncertainty in rocket position at the time of the receive window function. Sufficient effective radiated power (the product of transmit antenna gain and transmitter power) must exist over the entire volume defining the location uncertainty associated with the rocket position. As discussed in Section III C 2, the duration of time during which the receive window is open was 10 milliseconds. This parameter was held fixed in the system calculation although the impact of the choice of receiver window width will be evident in the discussion of tradeoff study results included in this section.

In order to effectively illuminate the rockets within their volume of uncertainty, there are three candidate locations for the transmit antenna:

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1) The antenna could be located in the nose of the helicopter and pointed directly forward. In this location the antenna would illuminate all the rockets when they are tens of feet in front of the helicopter. This location has several disadvantages, such as (1) the transmission path is nominally parallel to the rocket where the receive antenna gain is low, (2) the transmission path is parallel to and through the rocket plume resulting in attenuation, and (3) the transmitter and/or antenna occupies premium space in the nose of the helicopter. The major advantage of the location is that a single antenna can illuminate all rockets.

2) The antenna could be located on a wing, positioned between two pods. Two such antennas would be required, one for each wing. Again, the first two disadvantages discussed in 1) above are pertinent. A third disadvantage is that the wing contour would probably preclude a flush-mounted antenna design. An additional disadvantage is that the transmitter would not be simultaneously positioned near both of the spatially separated antenna requiring long transmission line runs. Such transmission line runs will attenuate the signal as well as require space to accommodate the runs.

3) The transmitter location judged most desirable was to flush-mount the antenna on the side of the fuselage. The precise location of the transmit antenna is a function of the rocket position uncertainty volume (RPUV).

    With the transmit antenna located on the side of the fuselage, (1) the transmission path avoids the plume of the burning rocket motor, (2) the transmission path is coincident with the present receive antenna's maximum gain direction, and (3) assuming the transmit antenna to be horizontally polarized, a good polarization match between transmit and receive antenna is maintained.

    Since the transmit antennas are radiating normal to the fuselage, interferences from the two transmitters are minimized. The relatively short range between the transmit antenna and the receive antenna enables a savings in transmitter power and/or receiver sensitivity. The possibility of a less sensitive receiver is advantageous when working in a hostile ECM environment and for avoiding accidental radiation from friendly sources. The major disadvantage of the approach is that two antennas (one for each pod pair) are required. Either a single transmitter with a power splitter or a dedicated transmitter for each antenna could be used. The latter approach would only require control cable runs to each of the remote transmitters as opposed to requiring RF runs if a single transmitter was employed.

In view of the superiority of positioning the antenna on either side of the fuselage, this system was assumed for all ensuing link calculations.

The fuze receive antenna system consists of four circumferential slots which are horizontally polarized. The broadside gain of a slot can be considered to be approximately 0 dB and have an omnidirection pattern for the purpose of these calculations. Hence, the receive antenna gain pattern is invariant with a rocket location within the rocket uncertainty volume. This is only an approximation since the combination of the four slot antennas with their respective detector circuits can result in a gain variation as great as ± 4 dB about the roll axis in the plane containing the four antennas. The ripple is caused by (1) interference between the slot antennas, (2) coupling between the four detector circuits, and (3) the mismatches in the diode characteristics.

The transmit antenna size depends on the size of the RPUV as well as the location of the volume relative to the front of the helicopter. As mentioned earlier, the size and location of the RPUV depends principally on the rocket motor temperature and the hardwired time delay between the reset pulse and the receive window function.

In summary, the link parameters that are considered variable in the ensuing link calculations will be (1) transmit gain pattern, (2) transmit antenna location on the side of the fuselage, (3) rocket temperature motor, (4) time delay between first motion and reset pulse, and (5) time delay between reset pulse and window function. The parameters considered constant include (1) receive window width, (2) receive antenna gain pattern, (3) receiver sensitivities, and (4) transmit power. The reason for fixing transmit power is that the received power is directly proportional to transmit power and that the other link parameters are not a function of transmit power.

Analytical Model

In order to perform the tradeoff study, a time sharing computer program was written to analyze the geometry shown in figure 1. The computer program solved the following communication equation:

$$P_{R_n} = \frac{P_T \, G_T \, \lambda^2 \, G_R \, \eta}{(4\pi)^2 \, R_n^2} \qquad n = 1, 2, \ldots, 8$$

where

$$P_{R_n} = \quad \text{received power for the } n^{th} \text{ slant range vector.}$$

$$P_T = \quad \text{transmit power.}$$

$$G_T = \quad \text{transmit antenna gain pattern.}$$

$$\lambda = \quad \text{operating wavelength.}$$

$$G_R = \quad \text{receive antenna gain pattern.}$$

$$\eta = \quad \text{efficiency of transmit antenna.}$$

$$R_n = \quad \text{slant range to eight positions describing the RPUV.}$$

The mathematical model used for each variable of the communication equation is discussed below. In particular the relationship of the equation variables to the link parameters, as previously discussed, will be covered. It should be emphasized that the model was kept as simple as possible, consistent with the present study goals. Hence, many approximations were made, the effects of which could be minimized in a more sophisticated (and costly analysis).

P_t, Transmit Power

A transmit power equal to 10 watts (peak) was assumed for all calculations. Since received power is simply proportionate to transmit power, the results for any other levels of transmitter power are directly obtainable. In addition, 10 watts is the present capability of RST-1 operating in a continuous data transmission mode which makes the results of this analysis directly applicable to present tests which use the RST-1.

R_n, Slant Range Vectors

The eight slant range vectors (SRV) which were used are illustrated in figure 2. They are dependent on the position of the transmitter relative to the nose of the helicopter, the near-in and far-out dimensions of the pods which define DNEAR and DTRACK, and the minimum to maximum distances traveled by the rockets, namely DDS and DDF measured relative to the nose of the helicopter. The value of DDS and DDF is based on experimental data, supplied by Picatinny Arsenal and discussed in more detail in the next section. The time-of-flight data pertinent to this study is the rocket time-of-flight from first motion to receive window

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function (window opening and window closing). This data is a function of time between first motion and reset pulse, time between reset pulse and window opening, and time between window opening and window closing. These three times plus the rocket flight data are all required as inputs to the computer program to determine DDS and DDF. Once the values of DDS, DDF, DNEAR, DTRACK, and DTRAN are computed, the eight slant range vectors are calculated in a straightforward manner from the problem geometry.
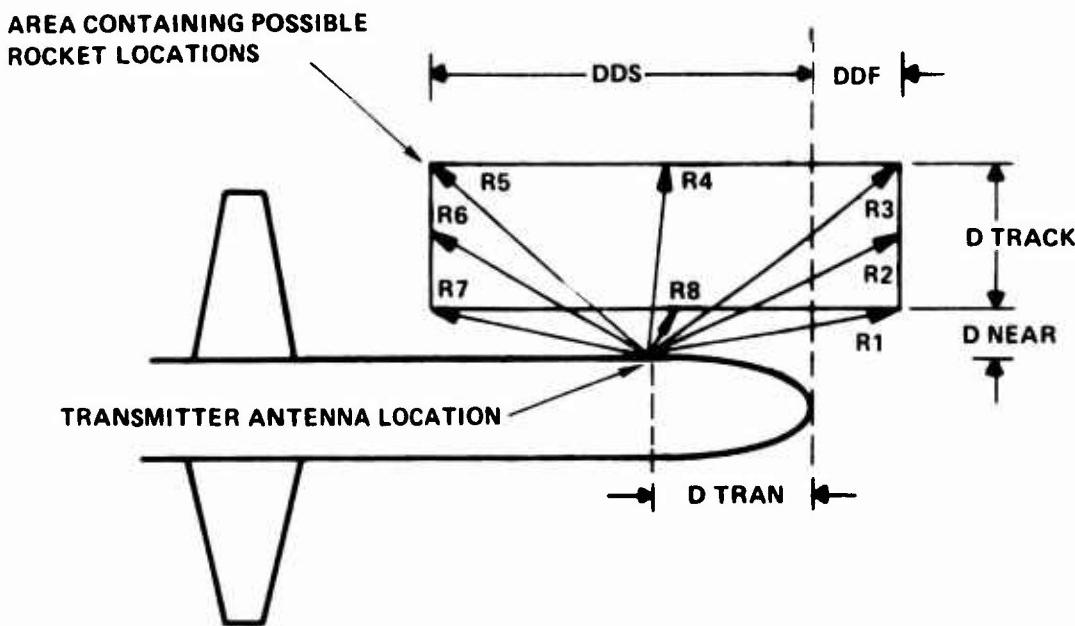
Figure 2. Computer Program Slant Range Definitions

The treatment of the rocket uncertainty volume relative to the elevation plane is covered later in the consideration of the transmit antenna gain pattern.

G_R. Receive Antenna Gain

The fuze receive antenna gain is approximately 0 dB ± 4 dB relative to an isotropic antenna. The 4 dB ripple accounts for the pattern variation with roll discussed in the previous section. It should be noted that this gain figure is indicative of an electrically small antenna. Hence, this gain value would result from most antennas that might be employed regardless of whether the operating frequency is the present X-band corresponding to RST-1 or a lower frequency. However, it may be possible to reduce the ripple by using a single axial slot and or designing a single diode RF detection circuitry. In the computer program an omnidirectional receive antenna gain pattern of 0 dB was assumed. Allowance for the ripple was incorporated by appropriately adjusting the required signal threshold level.

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G_T, Transmit Antenna Gain Pattern

The transmit antenna pattern must illuminate the entire RPUV which includes all possible rocket locations at the time of receive window function. If a larger volume is illuminated than necessary, transmit antenna gain is sacrificed. On the other hand, if too large a transmit antenna gain is used then the beamwidth will be too narrow to cover the volume "corners" as represented by the R_1 and R_7 vectors of figure 2, keeping in mind the magnitudes of R_1 and R_7 are less than R_3 and R_5. Because of the different magnitudes, a tradeoff between antenna beamwidth and range becomes evident.

The antenna which formed the basis for the transmit antenna consideration is illustrated in figure 3. The antenna consists of an array of slots constructed using stripline techniques. This construction produces a flush-mounted antenna. The slots have center-to-center spacings of nominally one-half wavelength in both height and width. The number of slots in height controls the elevation beamwidth while the number of slots in width controls the azimuth beamwidth. The peak gain is determined by the total number of slots. The gain of a slot will be equal to approximately 3, hence for N slots the overall antenna gain is 3N. The consideration involved in the selection of the transmit antenna design is discussed next.
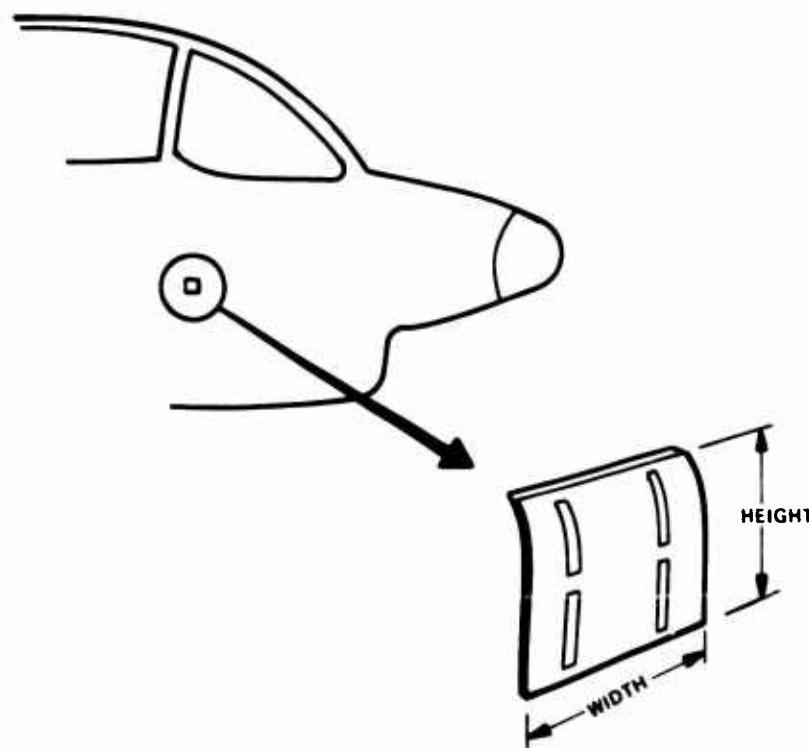
NOTE: TYPICAL ANTENNA DIMENSIONS ARE 1" x 1" x 1/4" AT X BAND.

Figure 3. Transmit Antenna Concept having Four Slots

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The elevation beamwidth requirement is dictated by the vertical displacement of the pods and the proximity of the pods to the transmit antenna as illustrated in figure 4. The geometry indicated an elevation coverage on the order of 60° was required. Since the elevation pattern of two slots oriented as shown in figure 3 would have a half power beamwidth on the order of 60°, the computer program fixed the number of slots in elevation at two.

REQUIRED ELEVATION
COVERAGE
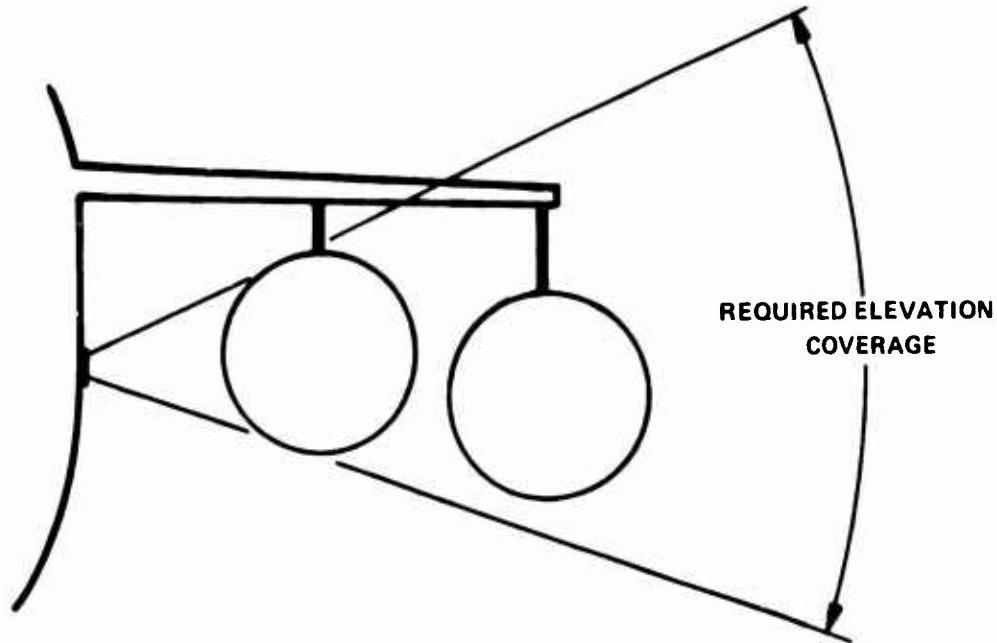
Figure 4. *Geometry for Determining Elevation Coverage of Transmit Antenna*

The number of slots required along the width of the antenna is a function of the area containing the rockets. Continuous coverage is required between vectors R_1 and R_7 of figure 3. Furthermore the transmit antenna should be pointed to maximize the minimum received power anywhere in the area of uncertainty. In order to establish the required number of slots along the width of the antenna (and consequently the overall width dimensions), the following procedure was programmed. The number of slot antennas was iterated starting with one. This had the effect of starting with an omnidirectional antenna pattern and then progressively making it more directive. The steering direction of the antenna for each number of slots was adjusted to maximize the minimum received power for the eight positions defining the RPUV shown in figure 2. A final antenna design would incorporate different fixed line lengths to the various slots which would cause the beam to electrically point in the desired direction. The iteration on the number of azimuthal slots was stopped when the azimuth pattern became so directive that the maximum power calculated began to decrease. The slant range vectors R_1 and R_7 are usually the limiting points since although their magnitude is less, their direction is at the extremes of the azimuth pattern.

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For most calculations performed in the next section, the number of slots along the width was usually no greater than two. These cases correspond to a $2 \times 2 = 4$ slot antenna which would have a gain of $4 \times 3 = 12$. The dimensions of such an antenna would be 1 wavelength x 1 wavelength corresponding to only a 1" x 1" antenna at X-band. The depth of a stripline antenna would be very small, perhaps no greater than 1/4 inch.

λ, Operating Wavelength

The computer results were all based on an operating frequency of 9.375 GHz, that of RST-1.

As seen from Equation (1) operation at a lower frequency (greater λ) would increase the received power. However, this is so only if the transmit antenna size is also increased to maintain the same gain (and therefore the same angular coverage).

η, Transmit Antenna Efficiency

In order to realistically account for the losses that would inevitably result with the transmit antenna, the antenna was assumed to have a 65 percent efficiency.

Tradeoff Study Results

The study results obtained by exercising the previously described computer program are presented in two parts. The first calculations are based on flight profile data supplied by Picatinny Arsenal prior to the range tests described in Section III F. The second set of data is based on the results of the range tests.

The initial system calculations utilized the customer-supplied data shown in figure 5. Shown plotted in the figure is time from first motion to window function, based on a 10 millisecond window. The spread in the data is mainly attributed to various possible rocket temperatures. Consider as a specific example $t = 0.14$ second. Referring to the figure, a cold rocket will have traveled to within 11.4 feet of the helicopter nose. However, a hot rocket will have traveled to within 5.8 feet of the nose. Hence, depending on the rocket temperature the fuze receiver can be anywhere within the $11.4 - 5.8 = 5.6$ feet spread.

It should be noted that some of the 5.6 feet uncertainty is the result of the rocket travel during the 10 milliseconds between the opening and closing of the receive window.

Consider next the situation where the system is designed for a window opening at t seconds, but due to unpredictable system errors, the window opening is at t_o where $t-\Sigma \leq t_o \leq t+\Sigma$. In other words, the window opening actually occurs during $t \pm \Sigma$ seconds after first

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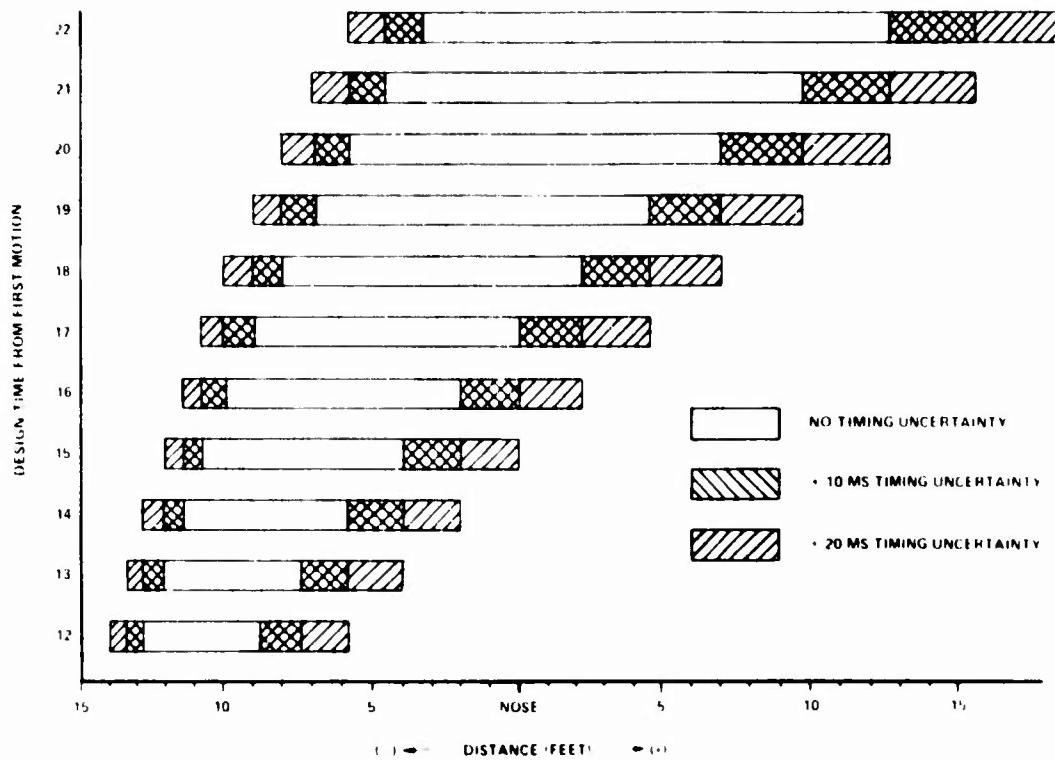
Figure 5. Window Function vs Location for 10MS Window

motion. The possible rocket position for t ± 10 milliseconds and t ± 20 milliseconds are also shown in figure 5. Note, for example, the previous 5.8 to 11.4 feet spread is enlarged to a 2.2 to 12.8 feet spread for Σ = 20 milliseconds. Since the transmit antenna must provide coverage over all possible positions of the rocket, any inaccuracies in the timing will complicate the antenna design.

Computer calculations based on the time-motion data of figure 5 are presented in figures 6 and 7. A sample printout is given in figure 8 showing some of the data used to derive the final results. The discussion of the results starts most logically by considering the sample data shown in figure 8. The power received for each of the 8-slant vectors of figure 2 is tabulated for the input data shown in the table heading. The slant range (in feet) from the transmit antenna and the angle between broadside and the range vectors are also tabulated.

For the case shown, the included angle formed by the RPUV is 83.59^0 - (-72.12^0) = $1'5.71^0$. Hence, the transmit antenna must have a very large azimuthal beamwidth. This is born out by the data presented. The first table of figure 8 indicates a minimum received power of -15.44 dBm for a single slot (omnidirectional pattern in azimuth). If an attempt is made to use a more directive pattern such as obtained by two slots then the received power is far less than the -15.44 dBm value as shown in the second table. Note that near the peak of the beam (near Pt. No. 4) the power level does increase due to the larger antenna; however,

16
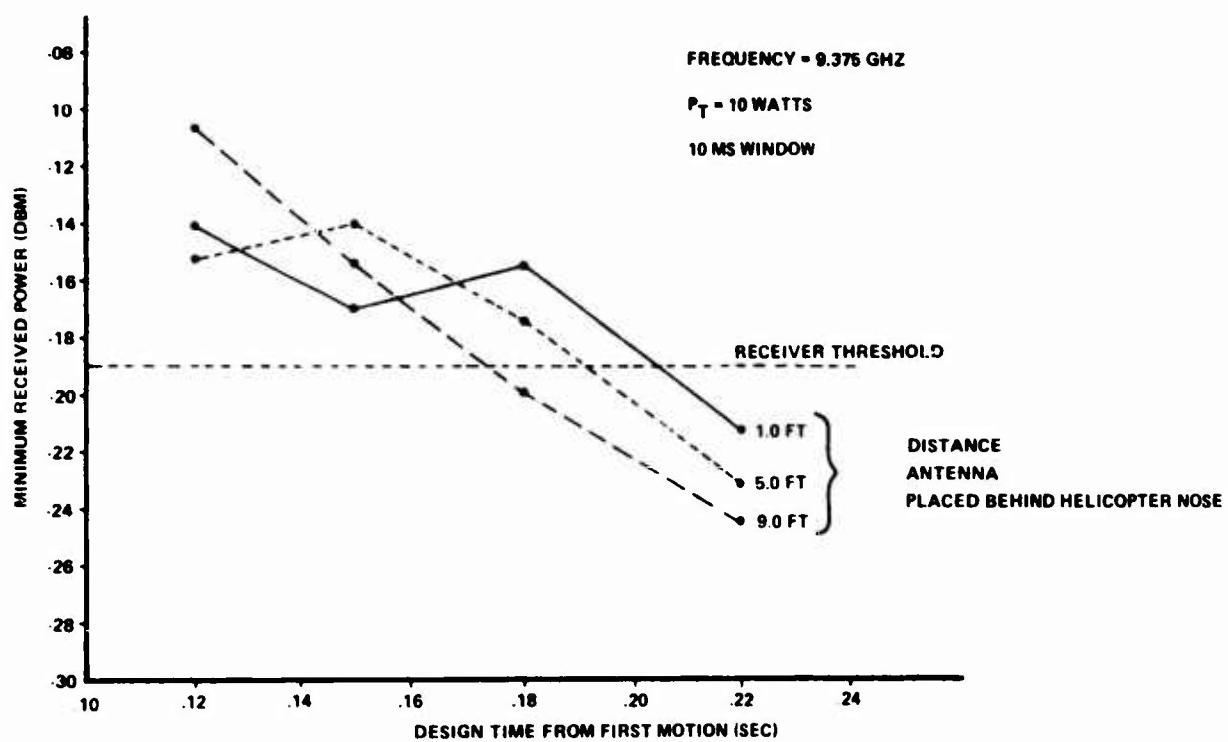
Figure 6. Minimum Power Received by Rocket for + 0.0 Second Uncertainty
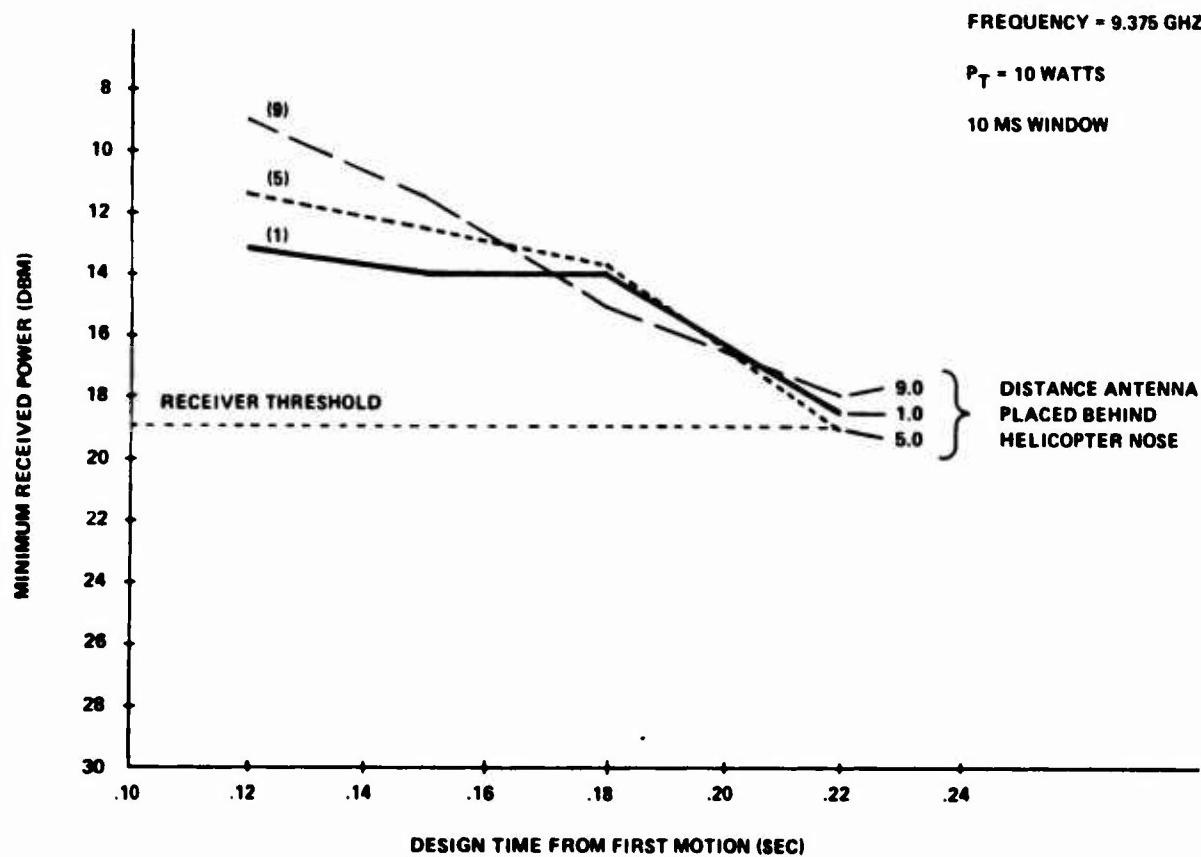
Figure 7. Minimum Power Received by Rocket for + 0.02 Second Uncertainty

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```
TRANSMIT POWER = 10.000 WATTS
FREQUENCY =  9.375 GHZ
TRANSMITTER PLACEMENT =  9.000 FEET
STEERING ANGLE =   14.01 DEGREES
TIME FROM FIRST MOTION =   0.15 SECONDS
NUMBER OF SLOTS =   1
TIME ACCURACY +OR-   0.02 SEC.


PT. NO.     ANGLE       RANGE   RCVD POWER(DBM)
   1        83.59       8.96       -14.70
   2        74.31       9.24       -14.97
   3        65.80       9.76       -15.44
   4        35.94       4.94        -9.53
   5       -37.78       5.06        -9.74
   6       -51.12       3.98        -7.66
   7       -72.12       3.26        -5.91
   8        70.97       3.07        -5.39


DO YOU WANT TO TRY DIFFERENT STEERING ANGLE(YES OR NO)?
=J


TRANSMIT POWER = 10.000 WATTS
FREQUENCY =  9.375 GHZ
TRANSMITTER PLACEMENT =  9.000 FEET
STEERING ANGLE =   20.71 DEGREES
TIME FROM FIRST MOTION =   0.15 SECONDS
NUMBER OF SLOTS =   2
TIME ACCURACY +OR-   0.02 SEC.


PT. NO.     ANGLE       RANGE   RCVD POWER(DBM)
   1        83.59       8.96       -26.98
   2        74.31       9.24       -22.37
   3        65.80       9.76       -19.51
   4        35.94       4.94        -7.26
   5       -37.78       5.06       -19.51
   6       -51.12       3.98       -26.78
   7       -72.12       3.26       -57.22
   8        70.97       3.07       -11.37
```

Figure 8. Range-Power Computer Printout

elsewhere the received power decreases. Observe, from the data, the option exists to steer the transmit antenna pattern peak to a value other than that selected by the program. The initial steering angle selection is to make the power received at Points 3 and 5 equal, whenever possible.

The results plotted in figures 6 and 7, as derived from the data of figure 5, are for time uncertainties of 0 and 0.020 second, respectively. The transmit antenna location was assumed at 1 foot, 5 feet, and 9 feet as measured from the helicopter nose.

There is a tendency for the power to increase when the center of the RPUV is directly broadside to the transmit antenna. In general, the received power decreases with increased design time from first motion since the range is increasing. (The prase "design time" is used to denote the period between rocket first motion and the receiver window turn-on pulse.) For each calculation, the number of slots comprising the transmit antenna was increased and the transmit antenna repointed until the power calculated decreased with increasing transmit antenna size. No attempt was made to use a transmit antenna whose size was not an integer number of slots wide. The slot spacing was one-half wavelength. A comparison of figures 6 and 7 shows that the time error of + 0.020 second causes approximately a 2 dB decrease in received power. The best position for the transmitter depends on the design time from first motion.

The required received power depends on the receiver sensitivity. Based on laboratory tests the present fuze design has a sensitivity of approximately -19 dBm. This threshold is also plotted in each figure. It is emphasized that this threshold does not include any safety factors.

To show the effect of rocket motor temperature on power requirement, the results shown in figure 9 were computed for an ambient temperature rocket with no timing errors. The only quantity causing a spread in the rocket position at a given time was the 10 milliseconds during which the window was open. For the case of the ambient temperature rocket, a larger gain transmit antenna could be employed due to the smaller beamwidth requirement. Comparing figures 6 and 8, approximately 2 - 3 dB less transmit power would be required for smaller times from first motion if the uncertainty associated with rocket temperature could be eliminated.

The results of figures 6, 7, and 9 indicate that the parameter values assumed for the study results in a safety margin of approximately 5 dB for design times from first motion out to approximately 0.18 second provided there are no timing uncertainties or that the rocket temperature can be controlled. The safety margin can be increased by reducing the receive antenna pattern ripple, increasing the transmit power, or increasing receiver power.
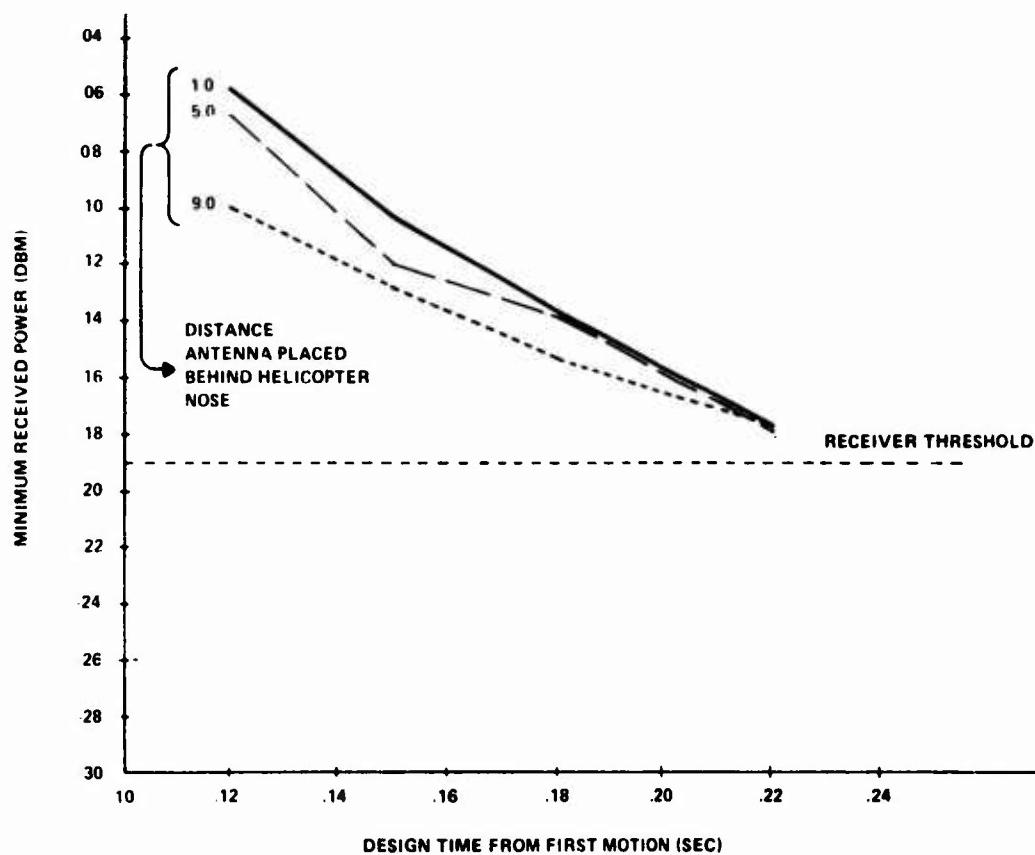
Figure 9. Minimum Power Received by Ambient Temperature Rocket with 10MS Window

The preceding computations were based on previously measured performance of FFAR rockets. However, during the week of September 9, 1974 tests were conducted at Camp Edwards, Massachusetts to measure the time delays during rocket firing for the remote set information link requirements. These tests are discussed in detail in Section F. The data pertinent to this study is presented in figure 10. Shown in the figure is customer-supplied data showing the positions of a cold rocket (-40°F) and a hot rocket (+130°F) as a function of design time from first motion with a + 10 millisecond time uncertainty and a 10 milliseconds window open duration. The time uncertainty is a result of time variation between the time from first motion and the reset pulse.

The phrase "design time" is used to reflect that the ordinate value is an errorless value. However, the distance shown incorporates the effect of the ± 10 milliseconds uncertainty. Since the time from first motion to reset pulse was nominally 20 milliseconds, the second ordinate scale is included, labeled design time from reset pulse to window function. This is the delay wired into the receiver logic discussed in Section III C 1. The actual receiver delay values selected were the 70 milliseconds and 110 milliseconds time from reset pulse to window

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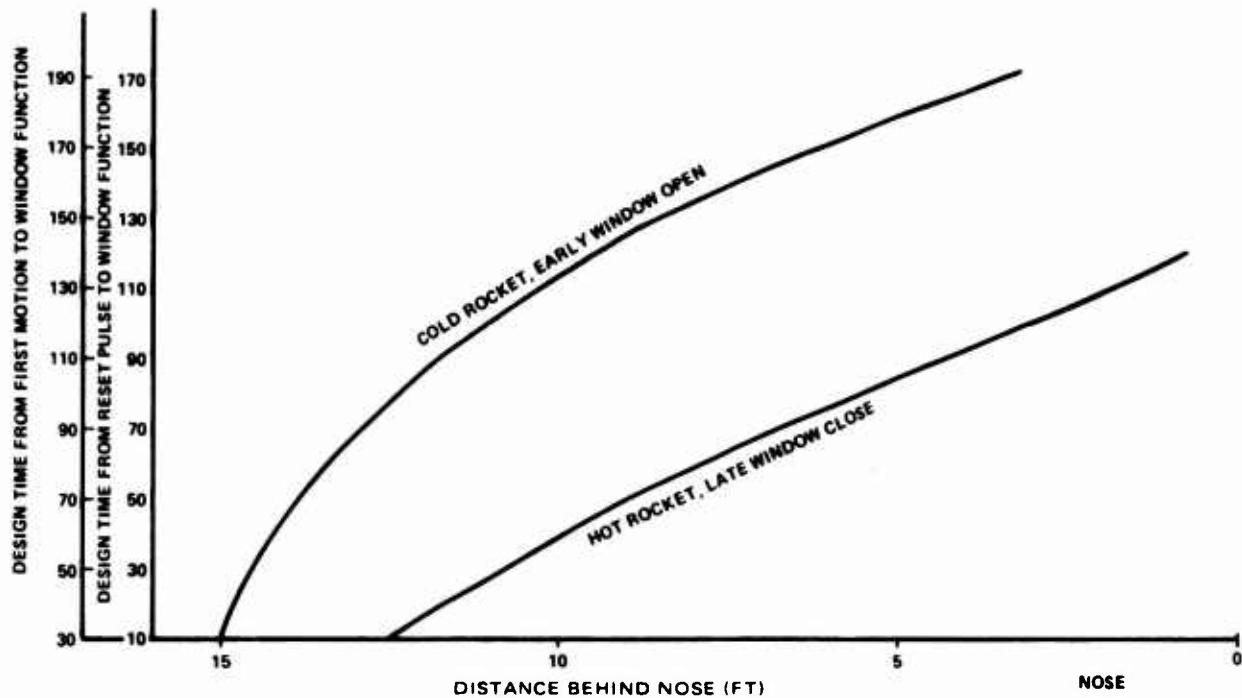
Figure 10. Camp Edwards Test Data Regarding Window Function vs Location for 10MS Window

opening. The leads for these two time delays were brought out of the receiver so that a choice could be made just before final mating of the receiver to the logic. As observed from figure 10 these times correspond to rocket uncertainties of -6.9 to -13 feet and -2 to -10.5 feet behind the rocket.

The minimum received power within the volume of uncertainty encompassing all possible rocket positions was next computed for the data given in figure 10. The result for two different transmit antenna locations is given in figure 11.

Again, a 10 watt source at 9.375 GHz was assumed. Generally speaking, the results are quite consistent with those previously obtained. In particular, there is approximately a 5 dB safety margin over the range of values considered. There is approximately 1 - 2 dB less received power when using the 0.110 second receiver tap compared to the 0.070 second tap.

System Tradeoff Study Summary

The best location for mounting the transmit antenna is along side the helicopter fuselage pointed nominally broadside to the helicopter. In this manner communication to the rocket is achieved as the rocket flies through the beam of the transmit antenna. The transmit antenna beam must be kept fairly broad to ensure that the rocket is within the beam at the time of

21
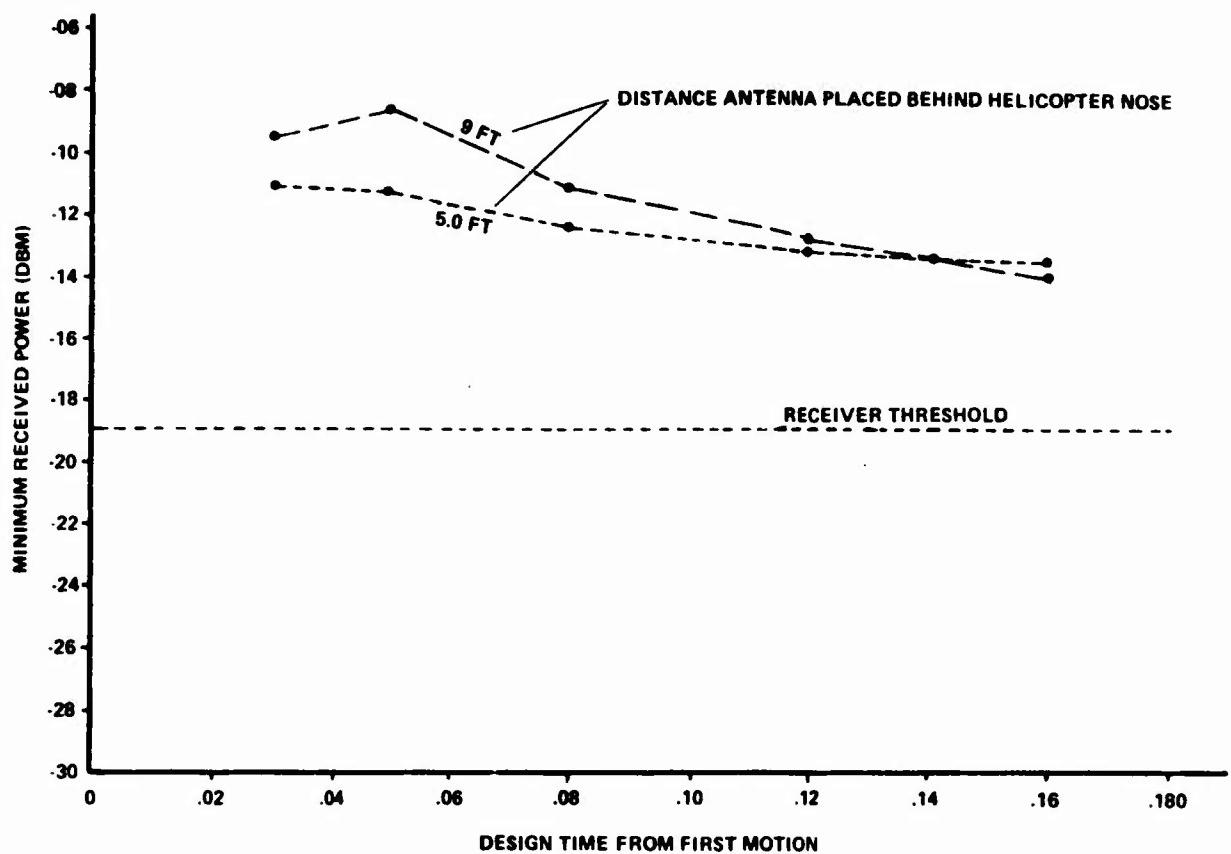
Figure 11. Minimum Received Power Based on Camp Edwards Test Results

window opening and closing. The location of the rocket at a given time is uncertain due to different rocket temperatures and timing errors that may be encountered in practice.

A computer program was written to determine the power received by the fuze while the window was opened for various combinations of parameters affecting the link. In particular, calculations were made comparing power received based on no time uncertainty with a + 20 milliseconds uncertainty and comparing an ambient temperature rocket with one whose temperature was unknown.

The minimum received power calculations were also made on the data obtained by the system tests discussed in Section III F. These results showed the received signal power to be approximately 5 dB greater than the present receiver sensitivity based on zero safety factor and a 10 watt transmitter. This margin could be improved by using a receiver antenna design with less pattern ripple in the roll plane, increasing the receiver sensitivity, or increasing the peak transmit power.

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B. DATA LINK DESIGN

1. TRANSMITTER CONTROL UNIT (TCU)

The multi-option remote set fuze uses a "window" signaling format which requires a signal to be continuously transmitted for a 100 to 250 millisecond period after the firing is initiated. The time delay information is encoded as the pulse repetition frequency (PRF), and the mode selection is encoded by transmitting narrow (0.7 microsecond) and wide (2.0 microsecond) pulses in varying ratios. The receiver uses an accurate 10 millisecond time gate to measure the PRF (i.e., count the pulses), and the first complete data cycle detected is used to select the fuzing option.

The basic operation of the multi-option TCU can be explained with reference to the block diagram of figure 12. A 100 KHz crystal oscillator drives a delay multivibrator (DMV) which provides a 100 KHz pulse-rate out, of 2.0 microseconds pulse width, hereafter called "wide pulse." These wide pulses clock a digital rate multiplier (DRM) which is controlled by three BCD thumbwheel switches (S3) to provide the desired ratio of output to input pulses. Alternately, the ratio could be set from an external logic-level source in parallel 3-BCD format (12 lines, plus ground). This ratio can be set to any number of 1/1000 to 999/1000. The output pulses trigger a 0.7 microsecond DMV ("narrow pulses") which feeds into a line driver and thence out the cable to the transmitter.
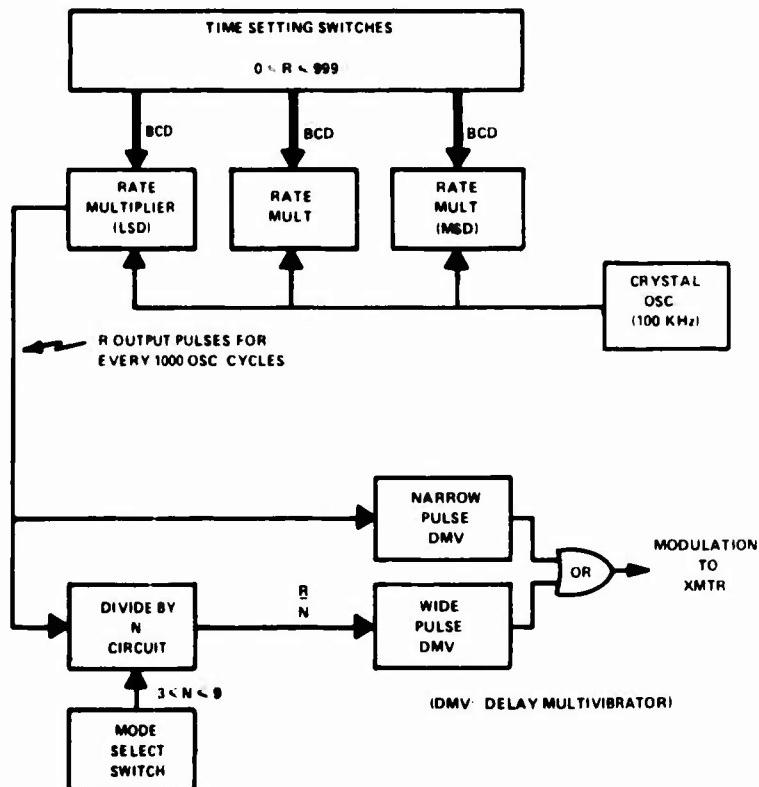
Figure 12. Transmitter Control Unit – Block Diagram

The wide pulses also drive a counter (or divider) whose counting modulus (M) is selected by the "Mode Select" switch (S2). M is selectable from 3 through 7, and gates every Mth-wide pulse through the "and" gate to the "or" gate and line driver. Thus the wide pulse, when present, will override the narrow pulse.

The detailed circuit schematic is shown in figure 13 and a photograph of the TCU is shown in figure 14. The new TCU interfaces with the transmitter (shown in figure 15) built under contract DAAA21-72-0013 for earlier remote set fuze studies. The circuit is constructed on a general purpose board, using 14 and 16 pin DIL sockets/plugs to connect to the switches and jacks. The power switch S1 retains the same three functions as in the original TCU: Off, Low Voltage only (Standby), and High Voltage enabled. The crystal oscillator uses two n-channel FET s and a complementary pair in Z5. The output drives the wide pulse DMV, the upper half of Z2, with pulse width adjustable by R12, which in turn clocks the DRM consisting of Z9, Z10 and Z11. The variable modulus counter consists of Z12 (a decade counter with decoded outputs), plus Z8a and b with the A-deck of S2 providing the Z12 reset after the selected variable count. Z1d passes every Mth wide pulse from the DRM, while the lower part of Z2 generates a narrow pulse (adjustable by R10) for each DRM output. These are "or-ed" in Z1c, and inverted in Z1a, which can also be switched by S2 to block this pulse train. This is necessary to allow inputting an external modulating signal ("auto set") on J1, with the two paths "or-ed" in Z1b before buffering into the line driver Z7.

The mode select switch has nine positions as follows:

1) Auto Set   The J1 input drives the line driver while Z1a blocks the internal signal path by grounding pin 1 via S2   B deck.

2) Test 1   provides all narrow pulses at a 999/1000 ratio.

3) Test 2   provides all narrow pulses at the (S3) Manual Set frequency ratio. R/1000.

4) Mode Select 1   provides one wide pulse per seven output pulses (six narrow) at the S3 frequency ratio (time setting). This enables only the "A" functions output, at the set time, in the demonstration units.

5) Mode Select 2 -- provides one wide pulse per six outputs (five narrow), at the S3 frequency ratio. This enables the "A" output at the set time, and the "B" output 1.28 seconds later.

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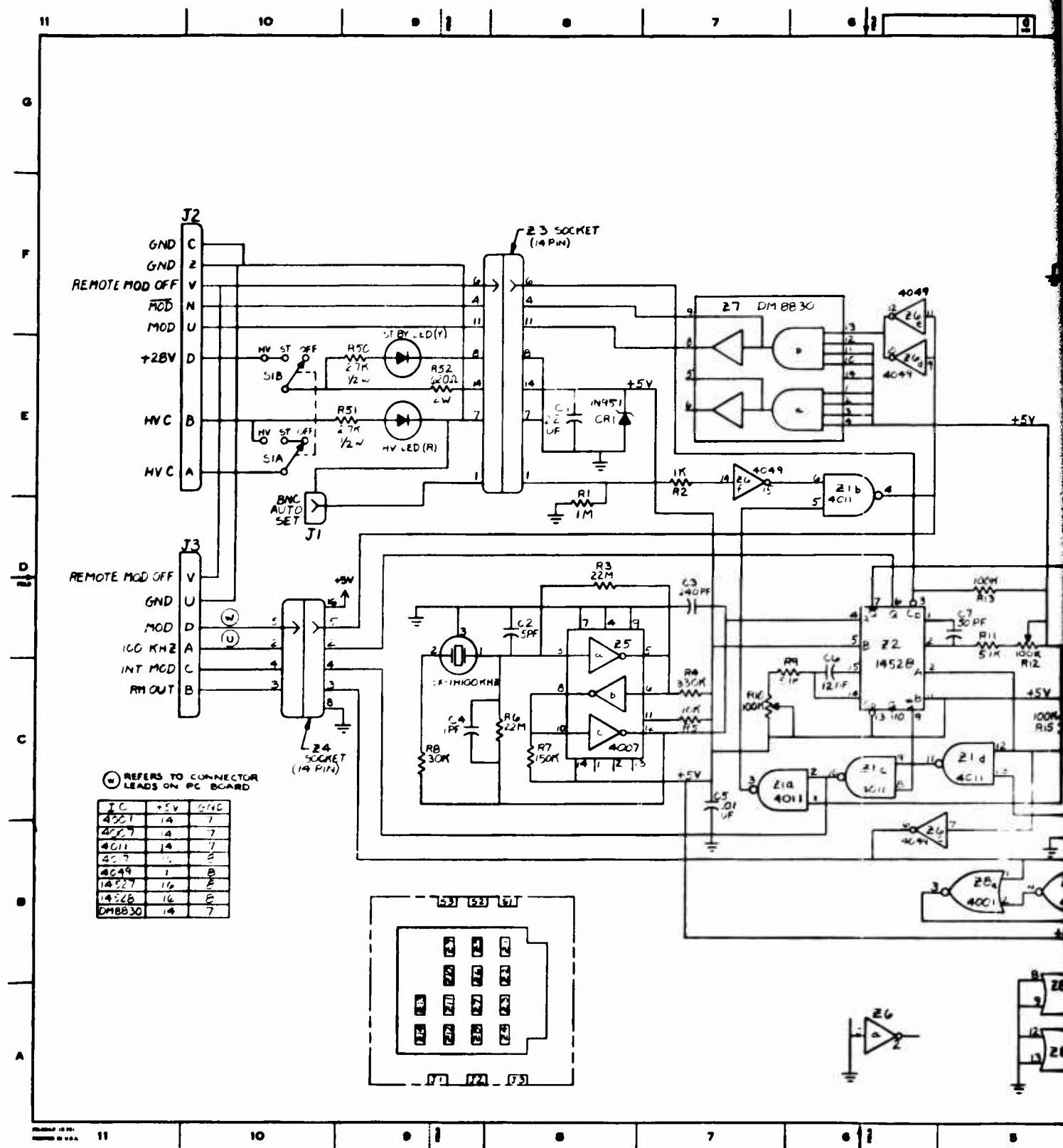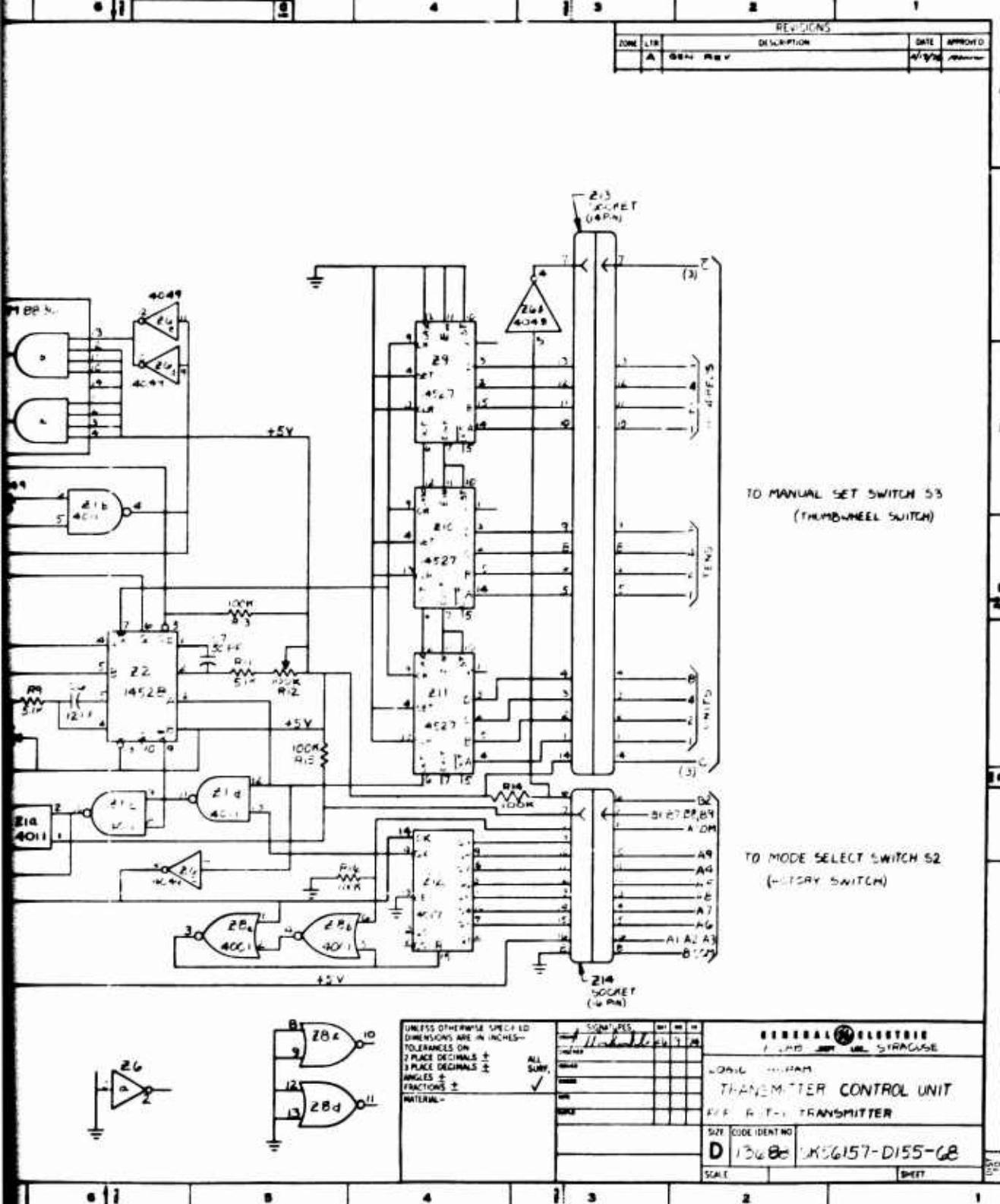
Figure 13. Transmitter Control Unit – Logic Diagram
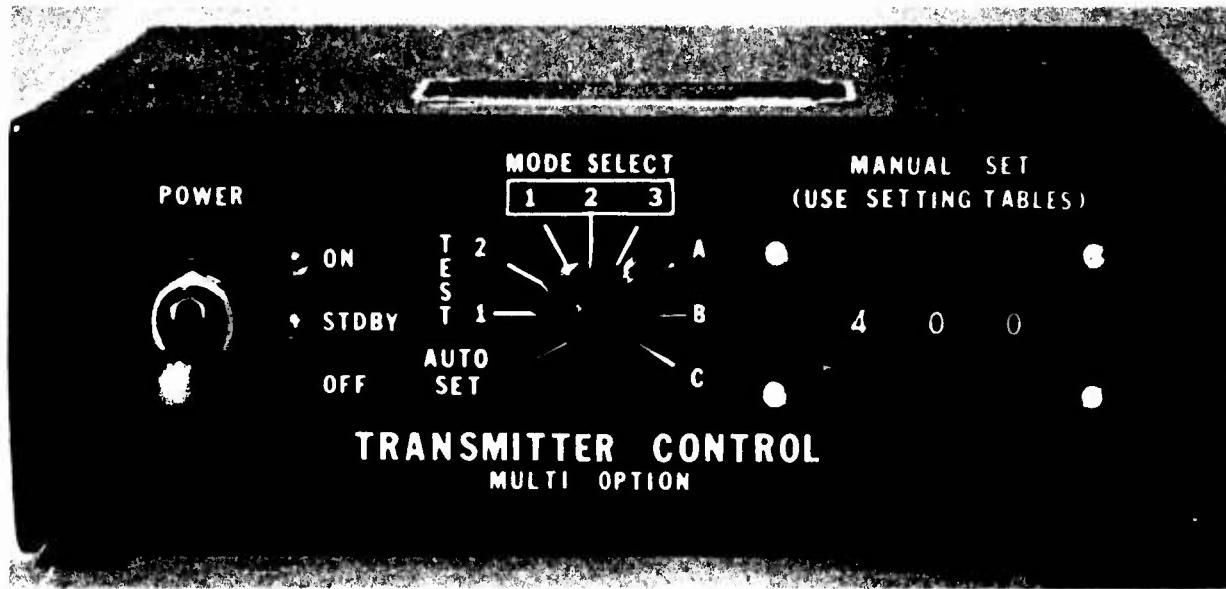
Figure 14. Transmitter Control Unit

Figure 15. Data Link Transmitter

6) <u>Mode Select 3</u> provides one wide pulse per three outputs (two narrow), at the S3 frequency ratio. This enables "A" and "B", as in MS2 above, and also "C" at 0.64 second after "A".

7) <u>Mode Selects A, B, and C</u> provide outputs of one wide per four, five, and eight pulses respectively. The demonstration fuze is not designed to identify these codes, but will treat them as an MS-1 code.

C. FUZE DESIGN

A basic block diagram for a multi-mode Remote Set (RS) fuze for 2.75-inch rockets is shown in figure 16. This figure has been drawn to emphasize the relationship of the multi-mode capability with the basic RS fuze which has been previously demonstrated, and which is contained in the lower half of the figure. The basic time fuze consists of a stable oscillator whose frequency is scaled (counted down) to a convenient period increment, in this case 100 Hz or 10 milliseconds. These cycles are counted until the counter fills, which initiates the fuzing function.
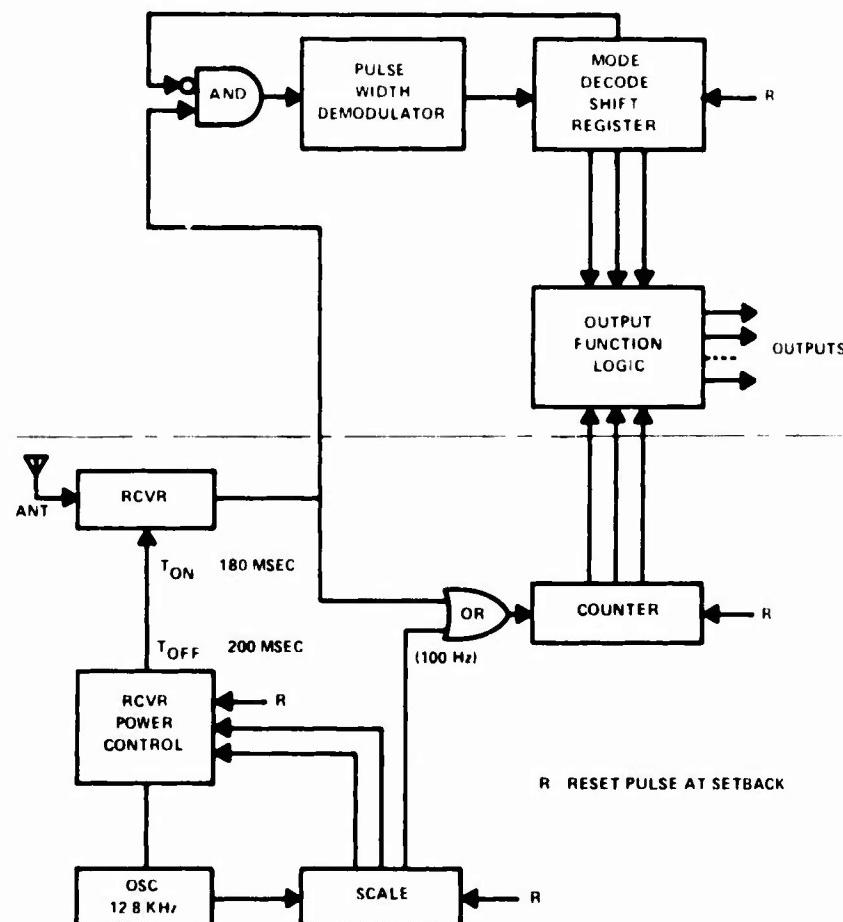
Figure 16. Fuze Logic Diagram
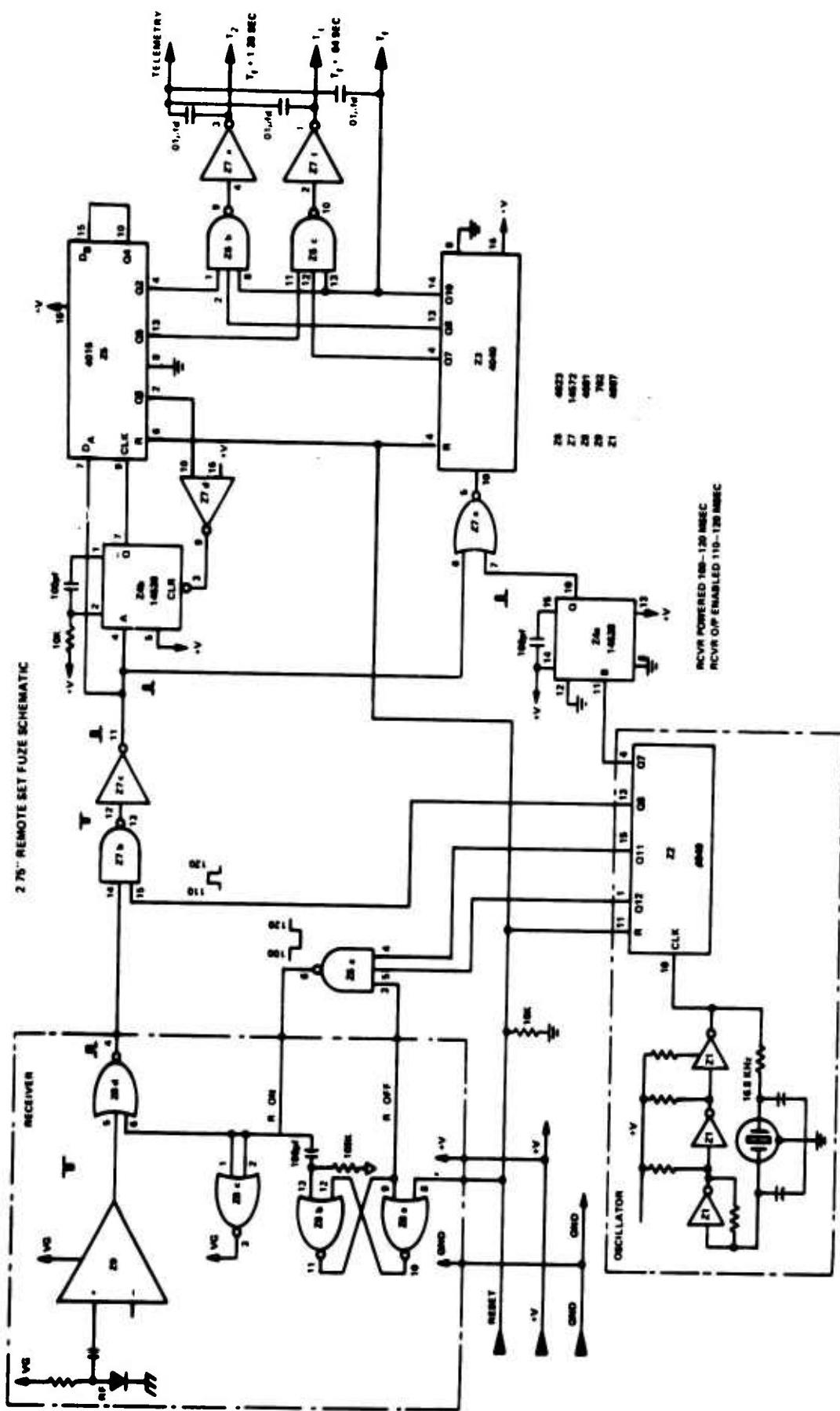
Figure 17. 2.75" Remote Set Fuze Schematic

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The RS path is through antenna and receiver amplifiers into the counter, with each rf pulse reducing by one the number of internal oscillator cycles required to fill the counter. In this case each rf pulse reduces the fuze time by 10 milliseconds from its 5120 milliseconds maximum. The fuze receiver is enabled for a fixed time period shortly after launch; the number of received rf pulses is determined by the transmitter prf as well as the receiver window duration. (This approach eliminates any requirements for close synchronization between transmitter and receiver and allows for salvo firing.) The window is generated by timing inputs from the scaler which provide power to the fuze receiver only during the brief window period.

The multi-mode option is provided by the functions in the upper half of figure 16. The information is encoded by transmitting two pulse widths; wide and narrow. Every N^{th} pulse is wide, the others are narrow, and N is selected (at the transmitter) in the range of 3 or 4 to 8. A pulse-width demodulator decodes the narrow and wide inputs to 0 and 1 binary outputs which are read into an 8-stage serial shift register. When a "1" enters the 8th stage the register is stopped, ignoring subsequent received pulses. The location of a "1" in the first five stages determines the selected option; and is combined with appropriate timing signals and sensor switches to activate the desired fuzing function. The "1" in the 8th stage provides the format framing. The minimum timing message must consist of $(8 + N)$ rf pulses, in order to insure receiving the mode select command, during the window period; this represents a minimal limitation on the maximum time; i.e., 15 out of 512 or 1024.

1. LOGIC CIRCUITS

The receiver/decoder schematic and logic waveforms are shown in figures 17 and 18. Directly identifiable parts include the oscillator Z1 and scaler Z2, the counter Z3, the shift register Z5, and the receiver video amplifier Z9. Z8 and Z9 are mounted in front of the antenna, as in the previous hardware, with the remaining circuits behind the antenna. Z8 (a, d and e), and Z6a perform the receiver power gating as described in Section III C 2, turning the power on at the time selected by the scaler taps, and off 20 milliseconds later. Z8b provides buffering and inversion on the Z9 output; Z7b passes the video pulses when Q8 of Z2 is high, thus reducing the effective rf window to the 10 last millisecond periods of the 20 milliseconds receiver powering period. This provides 10 milliseconds for Z9 to stabilize from turn-on transients. (Q8 of Z2 "enables" Z7b for the last 10 milliseconds of every 20 milliseconds period, but the receiver output Z8b is enabled for only one 20 milliseconds period which provides the overall 10 milliseconds one-time window.) Z4b is a delay multivibrator (DMV) having a delay period halfway between the wide and narrow pulses. This DMV is triggered by a positive signal transition to A (pin 4) with B (pin 5) held high. The output Q (pin 7) is normally high, but goes low when the DMV is triggered remaining low for a period determined by the R-C timing components connected to pins 1 and 2. This period is about one

30
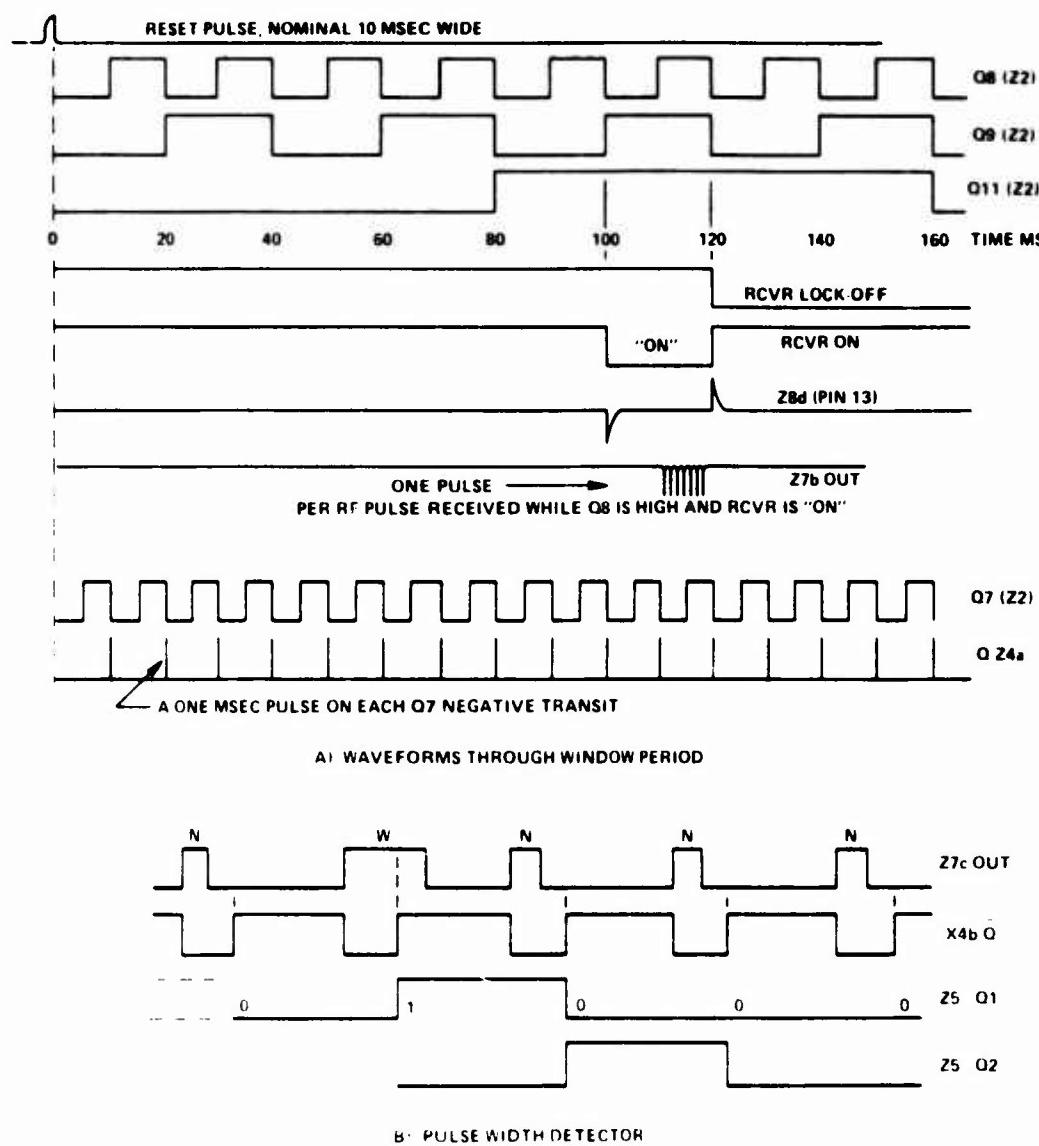
Figure 18. Receiver/Decoder Waveforms

microsecond with the indicated components. The "clear" input (pin 3) must be held high to enable DMV operation; when it goes low the DMV is immediately reset (Q returns high) and held in this state as long as the clear remains low.

Z5 is clocked by the trailing edge of the DMV $\overline{Q}$ pulse, which is one microsecond after the leading edge, causing either a 0 or 1 to be read at the data input line, corresponding to a short or long pulse. Z7d inhibits further triggering of Z4b when a "1" reaches Q8 of Z5. Z4a is another DMV used to shorten the period of Q7 out of scaler Z2. Z4a operates similarly to Z4b except the complementary trigger (B, pin 11) and output (Q, pin 10) are used and the clear (pin 13) is wired to the (high) enable state. The one microsecond pulse duration is a

negligible portion of the ten millisecond receiver gate. This allows using Z7a to combine the two pulse sources without requiring an "exclusive-or" gate — a hardware tradeoff using off-the-shelf IC's.

The time to output function, T_F is controlled by the time required to insert 512 clock pulses into Z3, at which time Q10 goes high. Those clock pulses received from Z2 arrive at a 100 Hz rate, that is a 10 millisecond interval. In the absence of pulses through the rf link Z9, T_F will be 512 (0.010) = 5.120 seconds. Each pulse received via the rf link will reduce T_F by 0.010 second. (A lower limit to T_F is established by the time position of the rf window.)

The output decoding is intended to provide mode confirmation by firing one, two, or three banks of flashbulbs. Mode 1 will fire one bank at T_F, the time determined by the transmitted prf. Here N may be 4, 5, 7, or 8. Mode 2 will fire two banks, one at T_F and another at T_F + 1.28 seconds, with N = 6. This leaves Q2 of Z5 high, and when Q8 and Q10 of Z3 go high at T_F + 1.28, a function enable will occur. Mode 3 will fire all three banks at times T_F, T_F + 0.64 second, and T_F + 1.28 seconds, with N = 3. This leaves both Q2 and Q5 of Z5 high. The particular decoding described herein is applicable only to the operation of the signature warheads intended for use during these demonstration tests. It is anticipated that slight changes in the circuitry would be required when interfacing with a tactical warhead.

The fuze logic package which finally evolved from the breadboard evaluation of these circuits is shown in figure 19. A complete assembly including the foamed oscillator package attached to the logic board as a separate module, is shown in figure 20.

2.   RECEIVER

The receiver schematic is shown in figure 21 and exhibits a degree of similarity to the receivers used on previous RS programs. There are significant differences, however, as summarized below: Because three NOR gates were needed for control functions, only one gate was available for use as a buffer. This required a no-signal-state-high output from the 702, obtained by making R3 larger than R4. Q1 provides gain and inverts the detected pulses, providing the required positive video pulse train at the 702 input. This minimized the circuit layout changes around the 702 amplifier which has always been quite prone to oscillate with any stray coupling.

The control functions are quite different on this receiver. Z8a is used as the power switch for the 702 (Z9) and detector bias circuitry, and is driven by the Z6a output (R-on) on the decoder assembly. Z8c and Z8d form a set-reset flip-flop, set by the reset circuit pulse when power is initially generated, and reset by the trailing edge of the R-on pulse via the differentiating R-C network. When reset, the Z8d output feeds back to a Z6a input to "lock out" further Z6a outputs.

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Figure 19. Fuze Logic Package
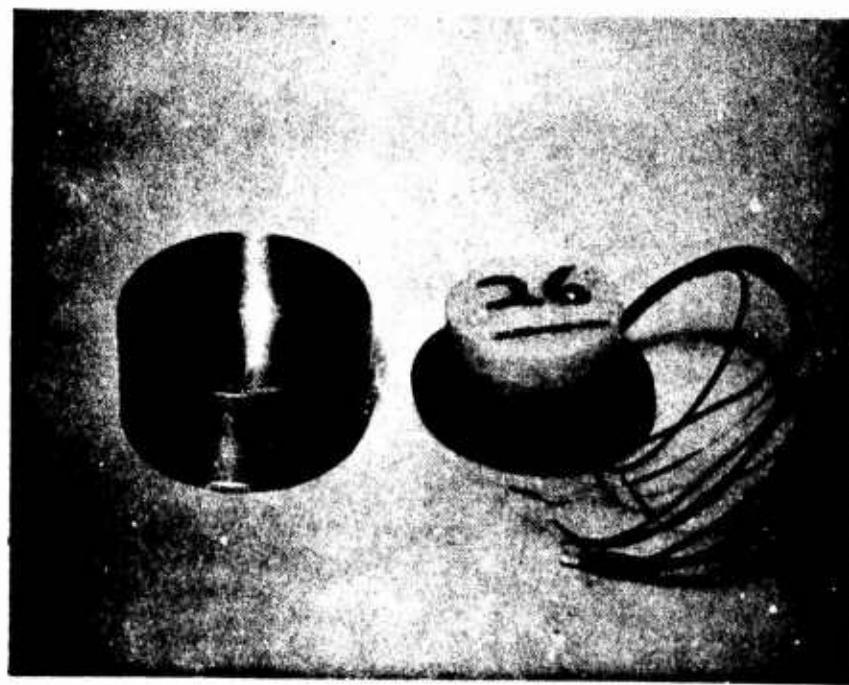
Figure 20. Fuze Logic Circuit with Oscillator Attached
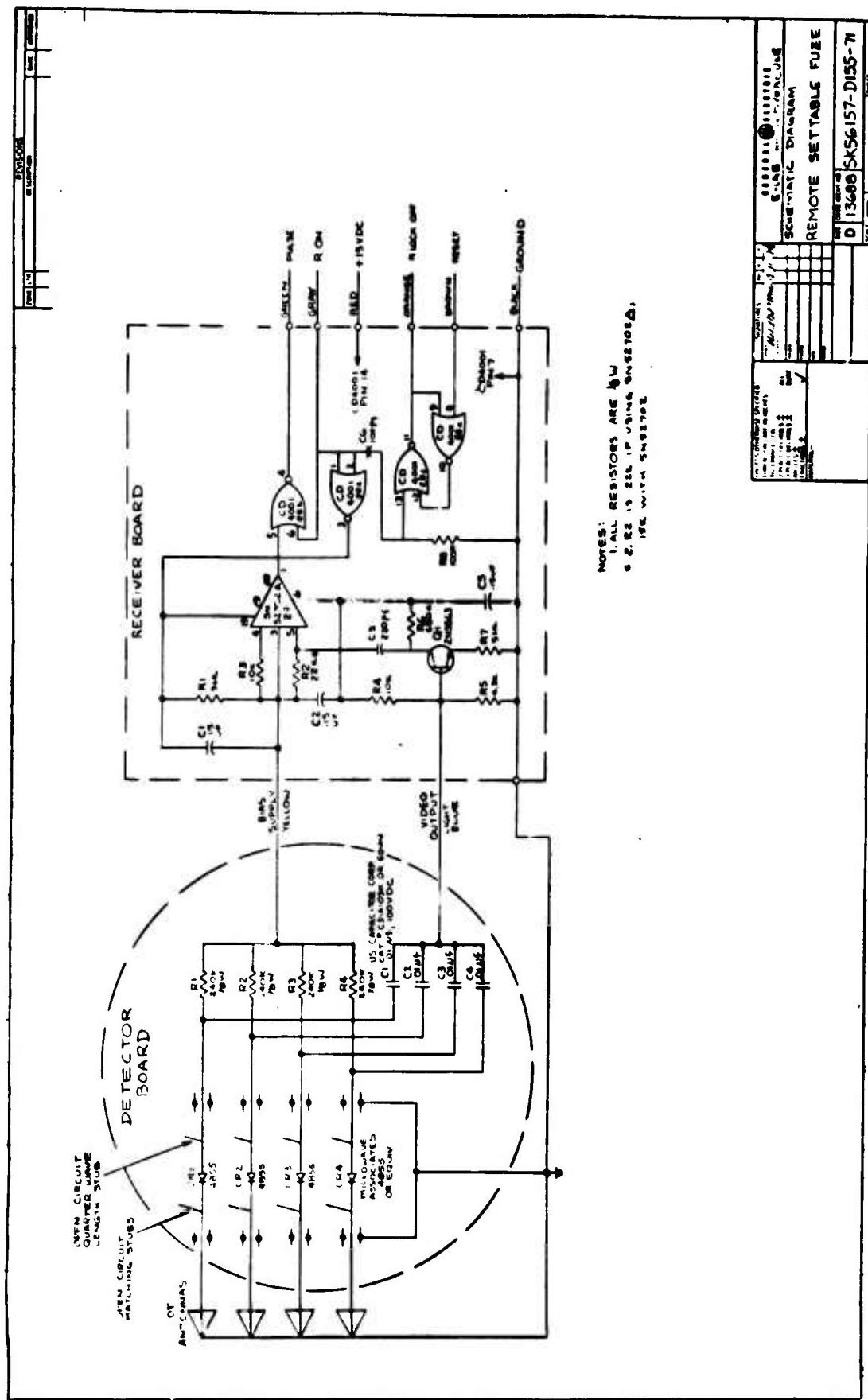
Figure 21. Fuze Receiver Schematic

Timing of the Z6a output is selected by taps on the oscillator scaler, Z2, fed to Z6a pins 4 and 5, are listed here:

TAPS	RECEIVER POWERED	SIGNAL ENABLED
Q9, Q9	20 - 40 milliseconds	30 - 40 milliseconds
Q9, Q10	60 - 80 milliseconds	70 - 80 milliseconds
Q9, Q11	100 - 120 milliseconds	110 - 120 milliseconds
Q9, Q12	180 - 200 milliseconds	190 - 200 milliseconds

Q8 from Z2 gates Z7 to enable the signal line only for the last half of the power period which blocks out oscillations frequently observed during the receiver turn-on transient.

During the circuit test and evaluation phase, several problems or limitations have been noted. The receiver is affected by supply voltage and performs best around 10-12 volts with pulse width reduction at higher voltages. Since the oscillator assembly requires a 15 volt start-up, the receiver will be operating at 14-15 volts. Some improvement in performance was made by reducing the Q1 gain brought about by reducing R6 from 1000 to 680 ohms. This significantly reduced the pulse narrowing problem under strong signal inputs, while sacrificing about 2 db gain at the low end. The dynamic range is now from about 0 dBm to about -25 dBm. Receiver power consumption is moderate, drawing about 4.2 ma at +15 volts, and 3.2 ma at 12 volts; this should drop the energy storage capacitor voltage by less than ¼ during the period that the receiver is enabled.

The receiver hardware as packaged within the fuze is shown in figure 22.

Figure 22. Receiver Hardware Package

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3. OSCILLATOR

The crystal oscillator and frequency scaler circuit is shown in figure 23. The oscillator utilizes the CD4007AE CMOS array and a Statek Corporation 12.8 KHz crystal. A three-stage amplifier is used, consisting of two n-channel FET's followed by a complementary pair.
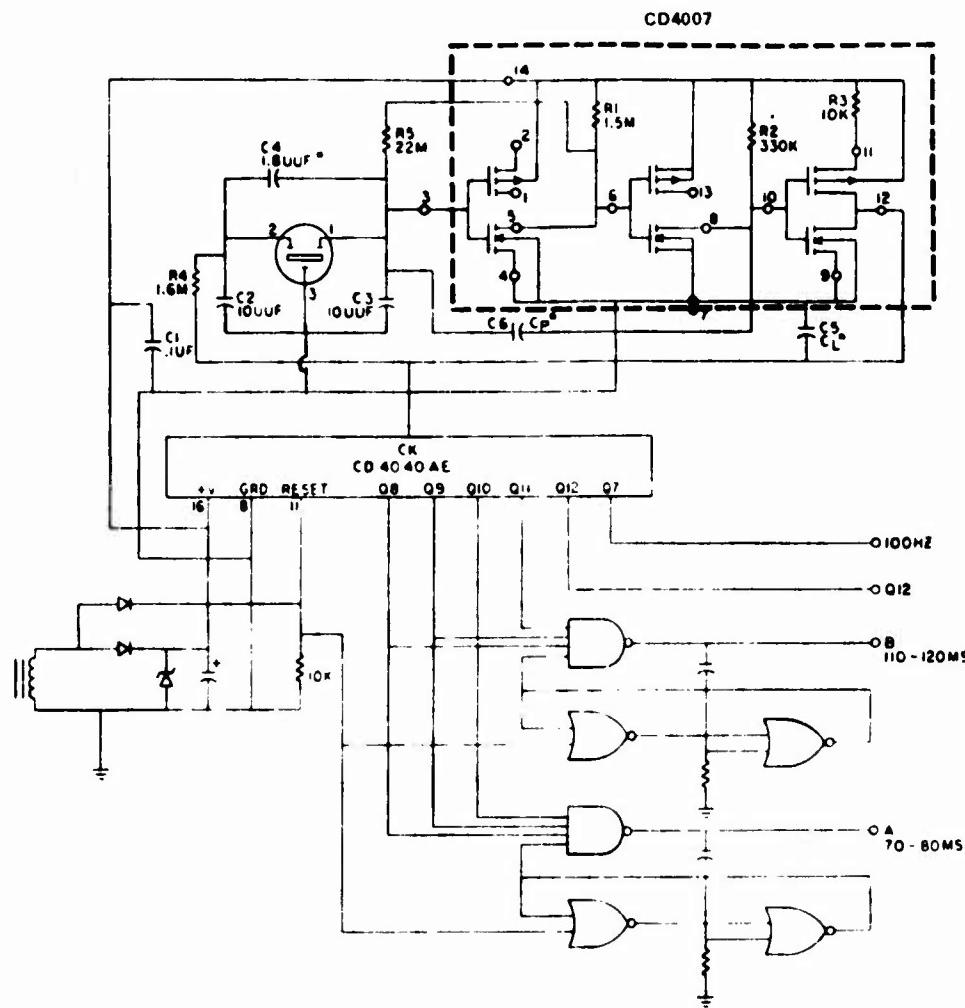
Figure 23. Crystal Oscillator and Frequency Scaler Circuit

The circuit is a crystal-stabilized, rather than crystal-controlled, oscillator in order to achieve a very rapid start-up when power is applied. The logic gates at the bottom of figure 23 are used as a test fixture to measure and trim the oscillator performance by measuring the following parameters:

a) Frequency – nominally 100 Hz from 7th divider stage.

b) Q12 delay – the period of the first 2048 oscillator cycles after reset is released.

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c) **A window** — checks the accuracy of the 10 milliseconds receiver window generated from 70 to 80 milliseconds after reset.

d) **B window** — same as A except at 110 to 120 milliseconds after reset.

The latter three give useful measurements of the start-up performance.

Several printed circuit board iterations (one of which is shown in figure 24) were necessary, as the circuit is extremely sensitive to stray coupling capacitances. C6 was implemented by facing copper areas on the front and rear sides of the PC board, and C4 must be selected by trial and error in the range of 1.5, 1.8, or 2.0 pF with final adjustment by physically bending C4. C5 is used, as needed, to eliminate high frequency oscillations during the start-up; values of 50-150 pF were required on a few boards.

Figure 24. Oscillator Printed Circuit Package

The crystal-stabilized oscillator will oscillate when the crystal is removed and replaced by its input and output capacitances. The (crystal-less) oscillator frequency exhibits a supply voltage sensitivity. The power supply (setback generator) has a 5 to 10 millisecond rise time; during this period the oscillation begins at a lower frequency and increases to a frequency above the crystal frequency. If the frequency sweep rate is slow enough when passing through the crystal frequency, the crystal apparently receives enough excitation to take control. The

increased loop gain, obtained by cascading three amplifier stages and adding the positive feedback of C6, seems to be a significant factor in achieving the "instant" start-up. Precise evaluation of the circuit has not been possible because of the extremely high impedance levels which prevent probing except after buffering by the scaler outputs.

The oscillator circuit becomes active as the power supply voltage rises above a few volts, but crystal control seems to occur only after voltages of 13-15 volts are reached. A circuit trimmed and operating satisfactorily with the 15v zener in the supply did not lock-in when a 12v zener was shunted across the supply. Possible reasons include:

1) failure of the unstabilized oscillator frequency to tune through the crystal frequency (f_x):

2) too fast a frequency sweep through f_x caused by abrupt thresholding of power supply (the 400 μf energy storage is well-matched to the setback generator at 15 volts, as indicated by the almost self-limiting evidenced by the rounded approach to the 15 volt level).

The scaler is held inactive until the end of the reset (coil) pulse; this gives the oscillator the duration of the pulse width to reach the exact (or closely approximate) frequency.

The test fixture is used with four frequency/period counters. One continuously measures the 100 Hz. The second measures the period from the back edge of the reset pulse to the Q12 transition, 2048 oscillator cycles (or 160 milliseconds at f_x). The third and fourth measure the period at each of two (potential) communication windows, providing a direct measure of the window accuracy. The window is generated by a 4-input Nand gate; the output goes low when Q8, Q9, Q10 (or Q11), and the SR flip-flop (composed of two Nor gates) all have high states. The SR flip-flop is set by the reset pulse, and reset by the trailing edge of the first window, thus providing only a single window for each operation of the setback generator.

A cautionary comment is also in order: Realistic start-up measurements require a "long" dead time before power is applied, in order that the mechanical crystal vibrations will have decayed to a negligible level. The crystal bandwidth is of the order of a second; decay times should be in excess of a minute, pending further studies.

Because of the circuit sensitivity to stray capacitances, it was considered necessary to encapsulate the oscillator/scaler circuit in a near-unity dielectric foam to provide isolation from the subsequent circuit potting material. Foaming was done in a two-step operation to minimize component deformation while the foam expanded. Very careful control was required to obtain a low density foam; and several ICs were destroyed, apparently by electrostatic

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effects during the foaming. The foam used was a two-part ISOFOAM PE-2A and PE-2B from Witco Chemical Corporation

4. SETBACK GENERATOR POWER SUPPLY

The General Electric Company, under contract to Picatinny Arsenal (DAAA21-73-C-0474), developed a setback generator for use in artillery fuzes. See figure 25. A subsequent program sponsored by GE demonstrated the use of a similar generator in a 2.75" rocket launch environment. This work was reported upon in the final report of Contract DAAA21-73-C-0764.
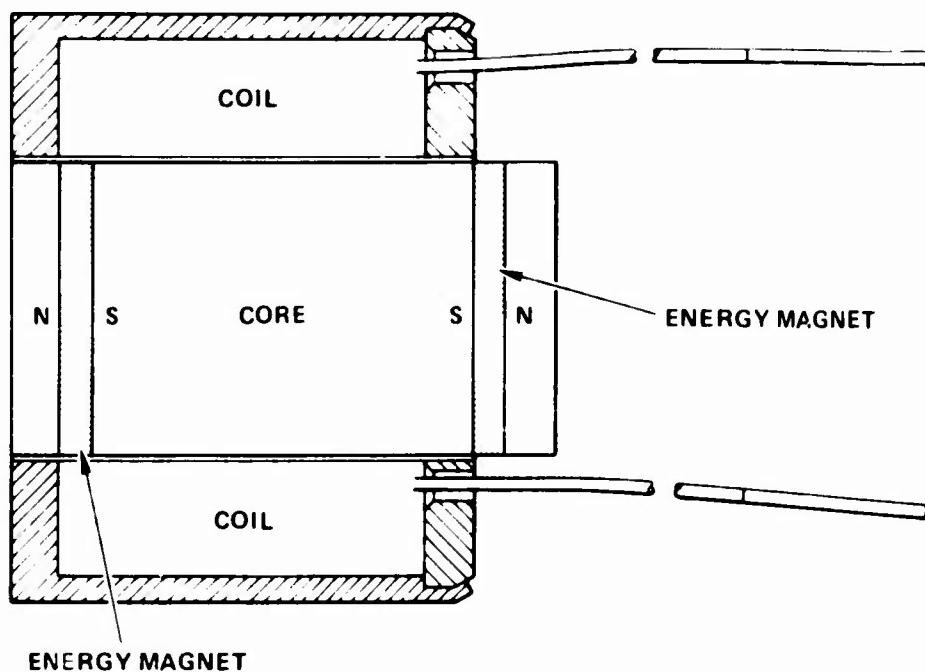
Figure 25. Early Generator Design

An improved version of this generator for use in 2.75" rockets was subsequently developed at GE. The new design incorporated both an electrical and mechanical safing feature, a requirement in a tactical munition.

The generator assembly tested under Contract DAAA21-73-C-0764 is shown schematically in figure 26 together with a force-displacement plot for that assembly. Note that the force required to drive the core through the coil is always positive, i.e., there is no "over-center" action to the core. Typically this generator produces about 288,000 ergs of energy in a simulated rocket launch environment of 25 g's. Figure 27 shows generator output curves for a range of acceleration inputs comparable to that which might be experienced over a normal rocket motor temperature range.
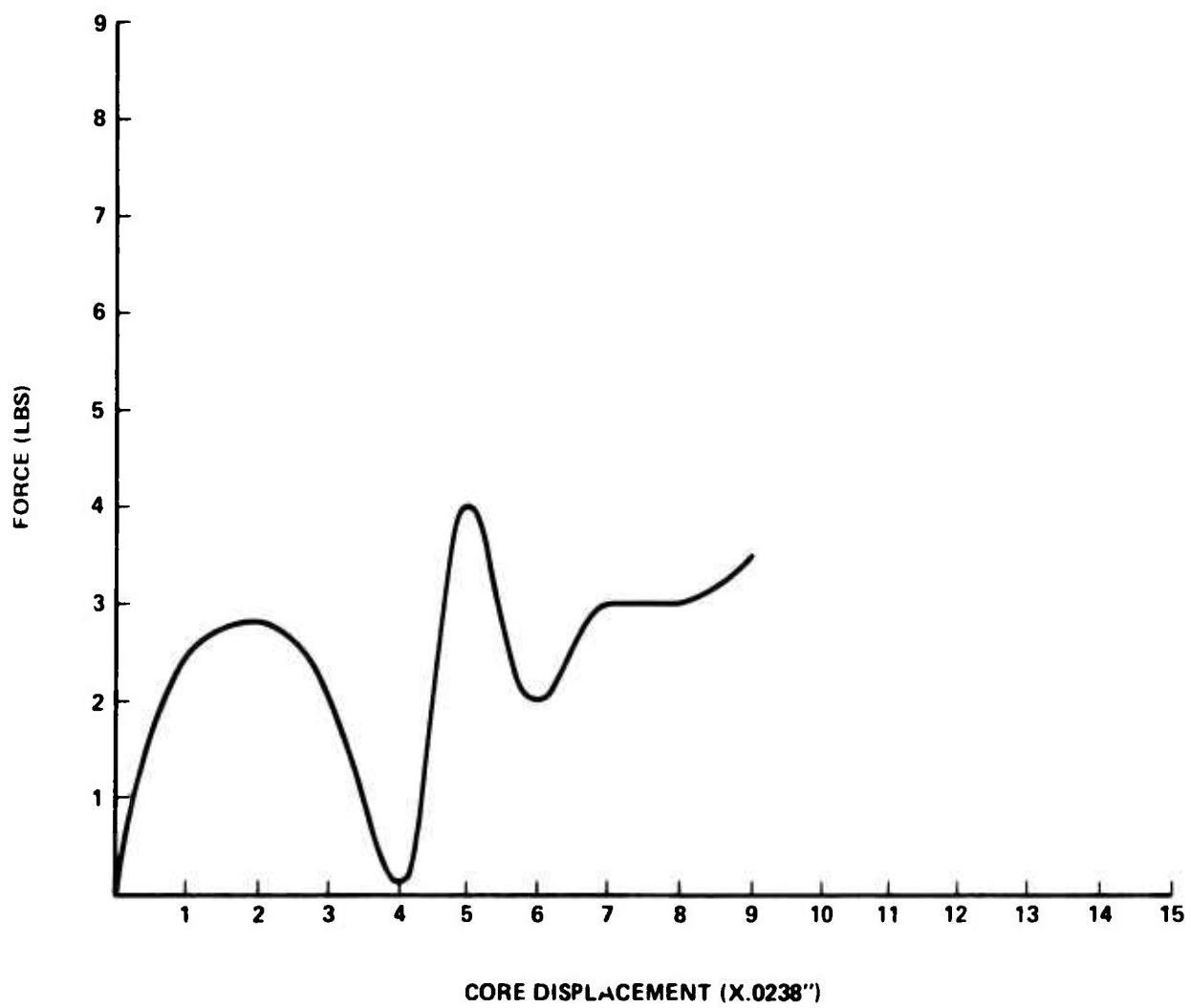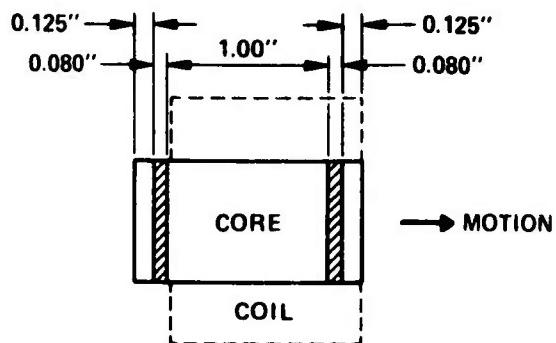
Figure 26. Setback Generator Schematic and Force Displacement Plot

GENERATOR OUTPUT
15 G'S ACCELERATION
INPUT (MOVING COIL
DESIGN)

ACCELERATION TRACE

10 G'S/CM

5 VOLTS/CM

GENERATOR VOLTAGE TRACE
(INTO 400 MFD'S)

10 MSEC/CM

10 G'S/CM

5 VOLTS/CM

AT 25 G'S ACCELERATION INPUT

10 MSEC/CM

AT 32 G'S ACCELERATION INPUT

10 G'S/CM

5 VOLTS/CM

10 MSEC/CM
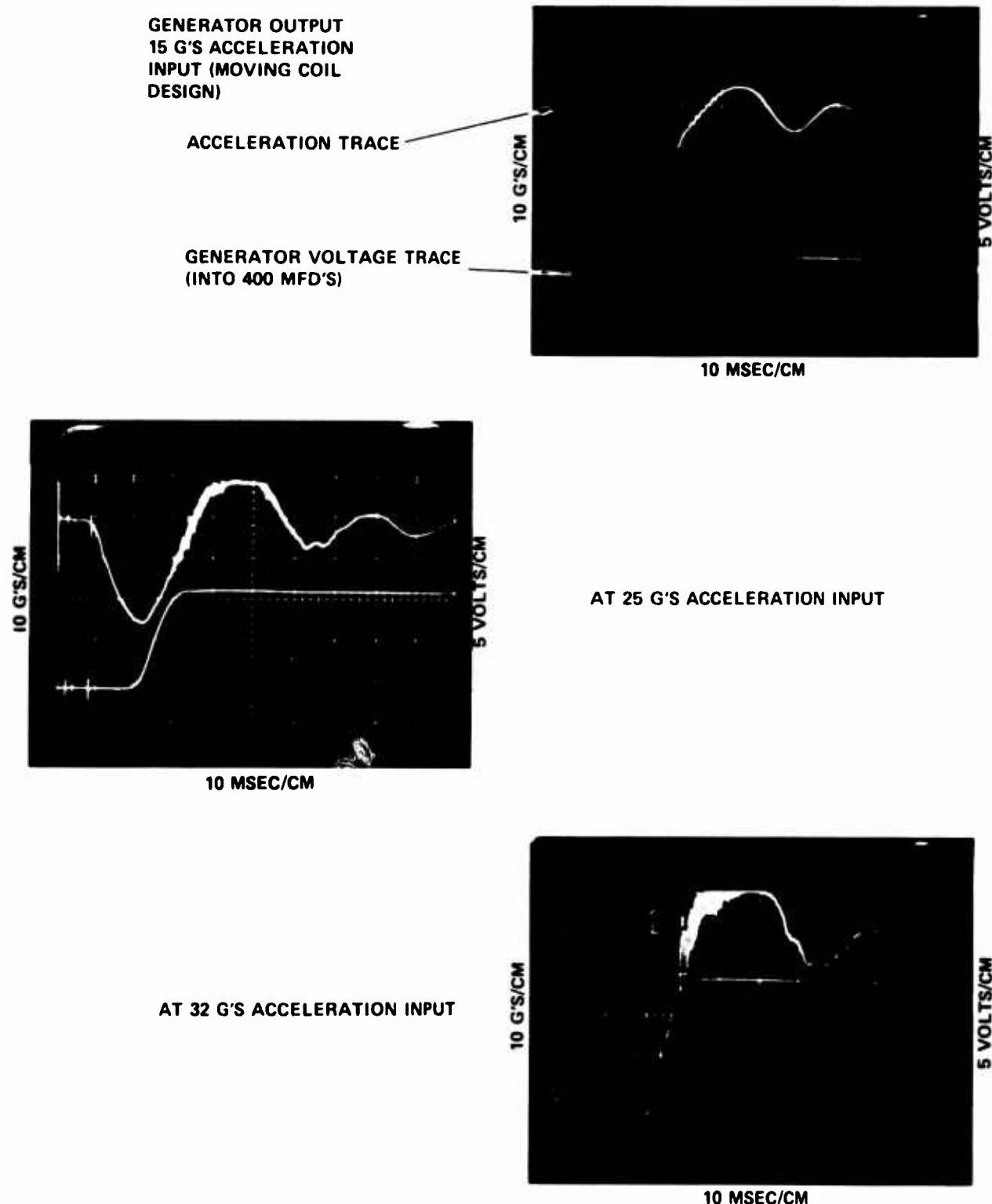
Figure 27. Early Generator Output Curves

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An electrically-improved version of this generator is shown in figure 28 and its accompanying force-displacement plot is shown in figure 29. Note the higher peak force required to drive the core through the coil and the "over-center" action (negative force) at a point along this curve. The higher forces are attributal to the larger magnets used in the new design. This higher drive force can be counteracted, however, as discussed below.
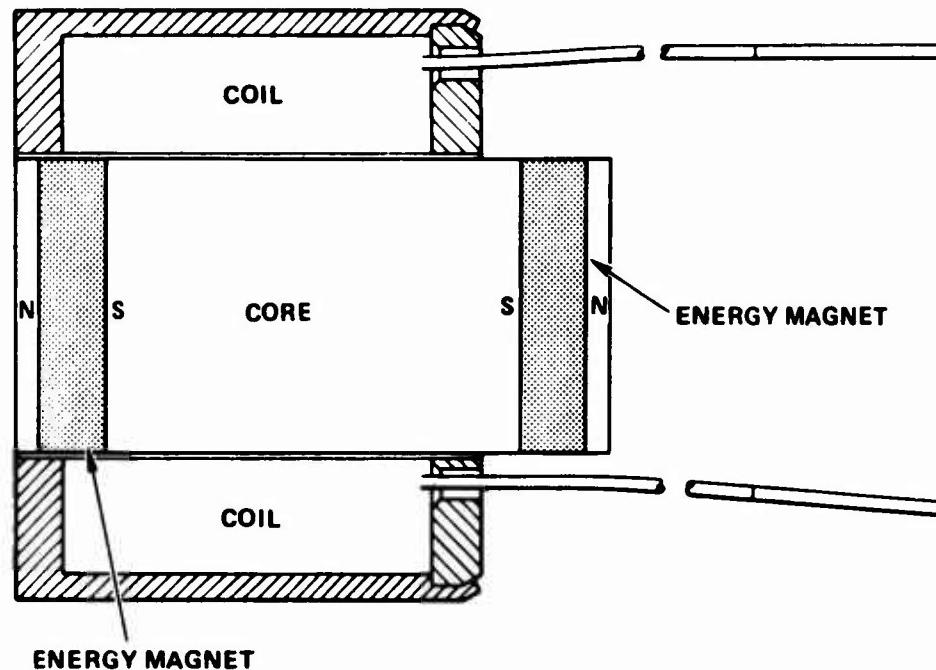
Figure 28. Improved Generator Design

The output energy from this generator is typically two times greater than that of the thin magnet design. A stronger magnetic flux field and a more optimum spacing between the magnets accounts for this increased performance. Voltage output traces taken at the extremes in acceleration input for this new generator design are shown in figure 30.

Threshold Sensitivity

As noted above, the new core design having larger magnets requires a higher peak force to push the core through the coil. This could be a problem in a low-g rocket launch environment since, below some acceleration input level, the core will not move. In earlier rocket tests of the setback generator (DAAA21-73-C-0764) a heavy mass was attached to the core to assure that it would be driven through the coil under the rocket acceleration load. The volume occupied by this mass was nearly equal to that of the core itself. With the new core design, the size of this weight would be more than twice that size to assure that the core would be driven through the coil under the expected acceleration load. Two approaches to circumvent this problem have been explored. In one case, the operation of the generator is

42
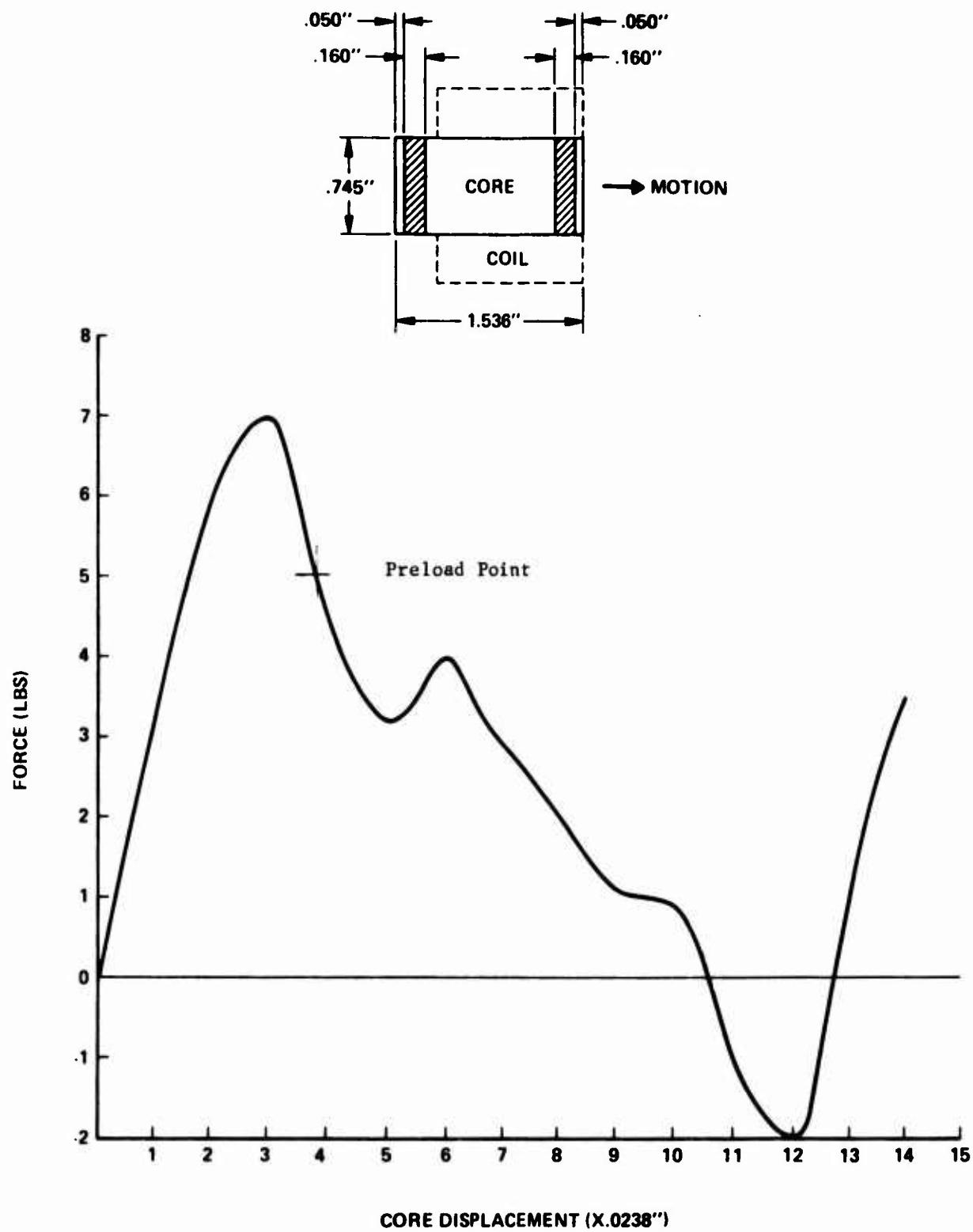
Figure 29. Force-Displacement Plot – Improved Generator

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IMPROVED GENERATOR OUTPUT
AT 21 G'S INPUT ACCELERATION
(MOVING COIL DESIGN)

10 G'S/CM

5 VOLTS/CM

10 MSEC/CM

10 G'S/CM

5 VOLTS/CM

AT 25 G'S ACCELERATION INPUT
(NOTE TIME BASE SCALE CHANGE)

5 MSEC/CM

AT 30 G'S ACCELERATION
INPUT

10 G'S/CM

5 VOLTS/CM

10 MSEC/CM
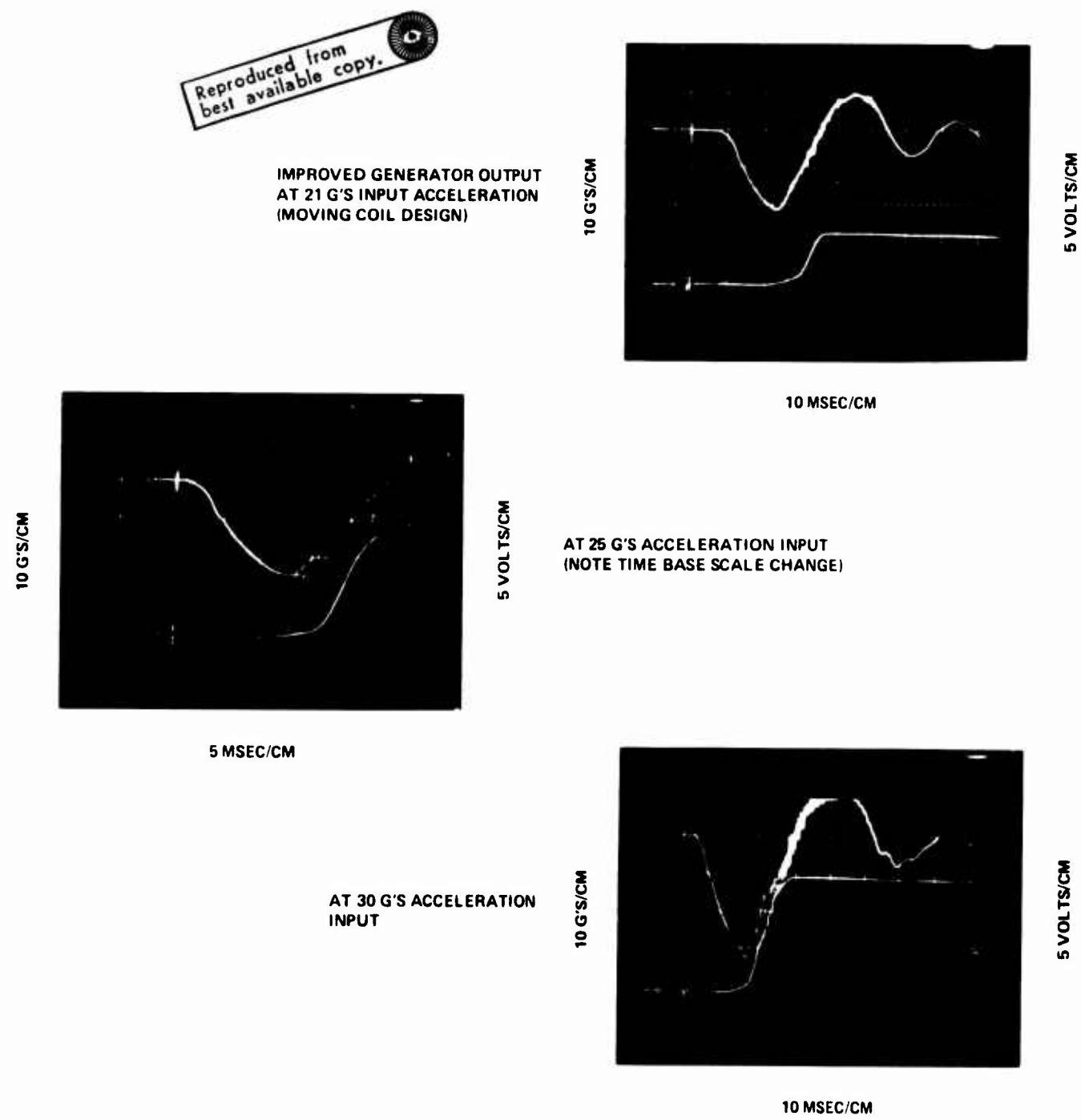
Figure 30. Voltage Output Traces – Improved Generator

altered to allow the (heavier) coil assembly to move while the core is held fixed in position. Since the coil assembly weighs about twice that of the core, a mechanical gain can be realized. Tests conducted using this (moving coil) approach show the acceleration threshold (for full generator output) to be about 25 g's as opposed to an acceleration threshold of 40 g's for the identical unit in which the core is allowed to move and the coil is fixed. See figure 31. This moving coil technique saves some "dead" weight which would normally have to be added to allow the generator to operate in the low-g rocket environment. The disadvantage of this approach, however, is that flexible wires would be required between the coil assembly and some fixed junction point to the electronic circuits within the fuze body.

GENERATOR OUTPUT
MOVING CORE DESIGN

10 G'S/CM

5 VOLTS/CM

10 MSEC/CM

10 G'S/CM

5 VOLTS/CM

GENERATOR OUTPUT
MOVING COIL DESIGN

10 MSEC/CM
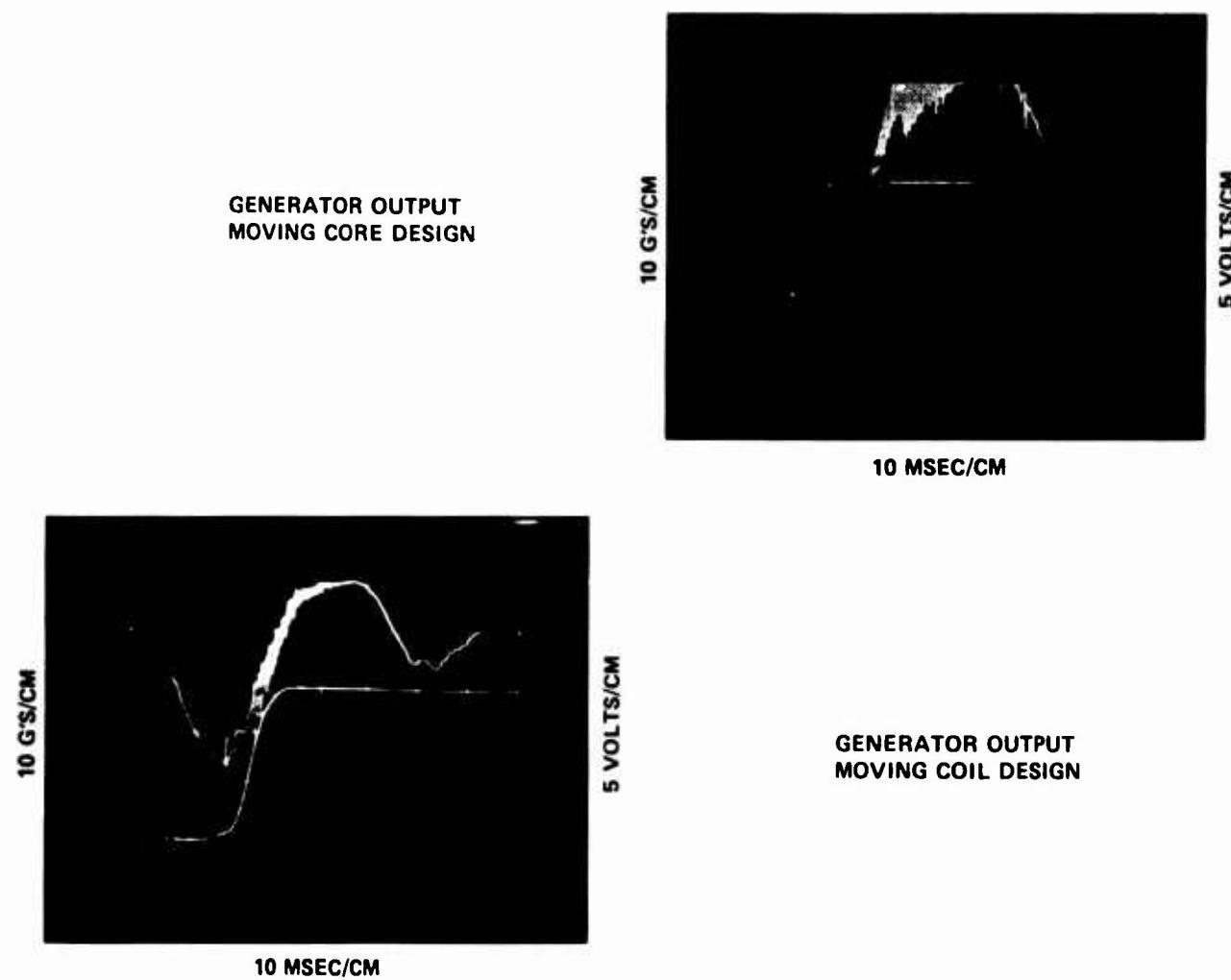
Figure 31. Moving Core and Moving Coil Generator Traces

45

An alternate approach which was investigated places a pre-load onto the coil assembly such as to reduce the force required (through an acceleration input) to drive the coil over the fixed core. The optimum value for this pre-load placed the coil at a point equivalent to about 0.096 inch of coil insertion. This point is identified on the plot in figure 29. Test results of this design (figure 32) show the generator threshold to have been lowered to about 15 g's, which is well within the range to be expected in a "cold motor" rocket launch. It should be noted that no springs would be required to pre-load the coil in this design since the magnets provide this pre-load force.

Generator Safing

Two approaches to mechanically safing the generator were investigated. One involved the expeditious placement and design of the energy magnets within the core assembly so as to produce a force/displacement plot of the type described in figure 29 of this report. Another approach was to employ a separate magnet within the core structure which served only as a safing function in the design. This approach is depicted in figure 33. A force/displacement plot of a core of this design is shown in figure 34. Following tests of this latter design, it was determined that the marginal performance improvement of this design did not justify its increased cost and complexity.

An electrical safing feature also explored in the new generator design is illustrated in figures 35 and 36. It combined the "magnetic spring" return force with a power supply shorting switch which assured that the energy stored on the capacitor bank was always shorted during periods of fuze storage and transit. It was designed to remove the power supply short and to remain open only if a sufficient acceleration force was presented to the generator. If this level was not reached, the core would be magnetically returned to its original position and the energy stored on the capacitors at that point would be "dumped". This effect is shown in figure 37. It should be noted that once the core had completed its full cycle it would not return to its start position due to the over-center action of the core assembly.

Of the three generator safing features discussed above only the first (figure 29) was employed in the deliverable hardware. Further development effort will be required before an electrical safing switch mechanism could be employed within the design.

Setback Generator Test and Evaluation

Following the design phase of the generator program, a small number of units were fabricated for laboratory test using an impulse type shock machine. This machine provides a shock input ranging from 5 to 200 g's in a period of 1 to 20 milliseconds. For purposes of our investigation the machine was programmed to provide acceleration inputs in the range of

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GENERATOR OUTPUT AT 23G
ACCELERATION WITH NO CORE
PRE-LOAD.

10 G'S/CM

5 VOLTS/CM

10 MSEC/CM

10 G'S/CM

5 VOLTS/CM
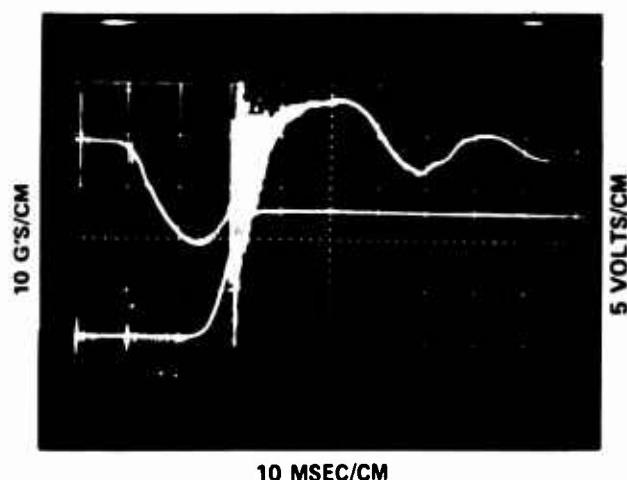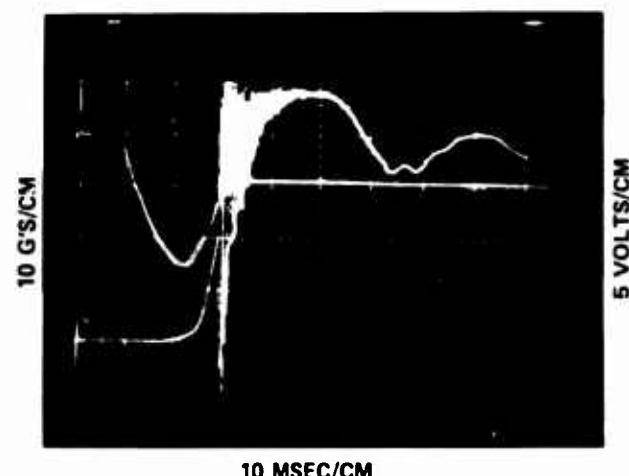
GENERATOR OUTPUT AT 20G
ACCELERATION WITH NO CORE
PRE-LOAD.

10 MSEC/CM

GENERATOR OUTPUT AT 15G
ACCELERATION WITH 0.096"
CORE INSERTION (PRE-LOAD).

10 G'S/CM

5 VOLTS/CM

10 MSEC/CM
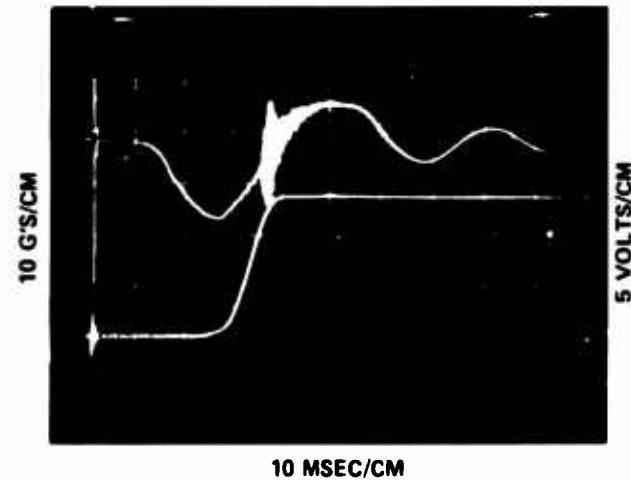
Figure 32. Coil Pre-load Test Results

47
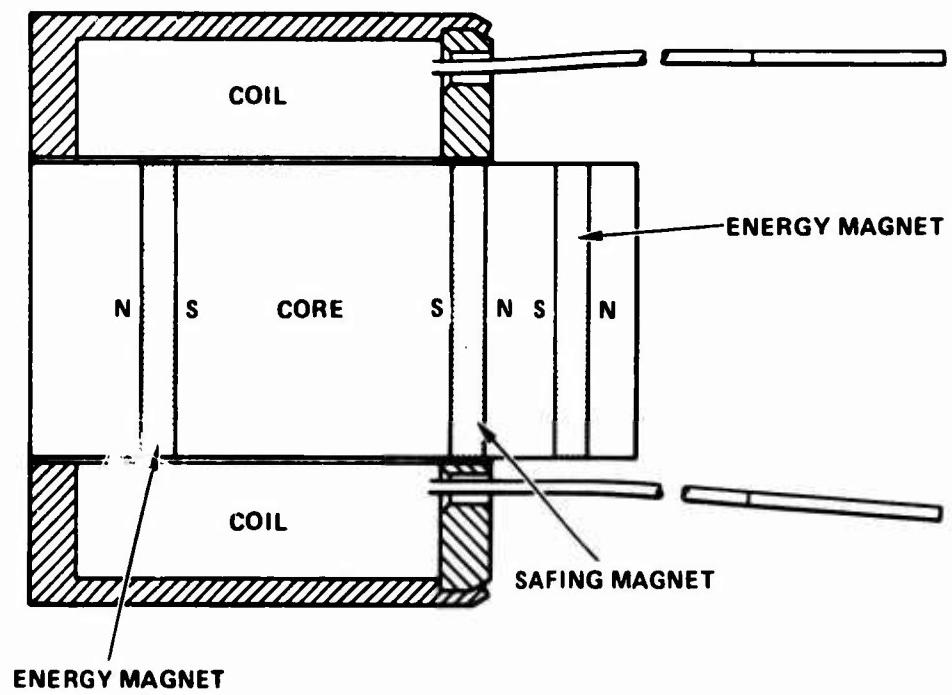
Figure 33. Core Assembly with Magnetic Safing Feature
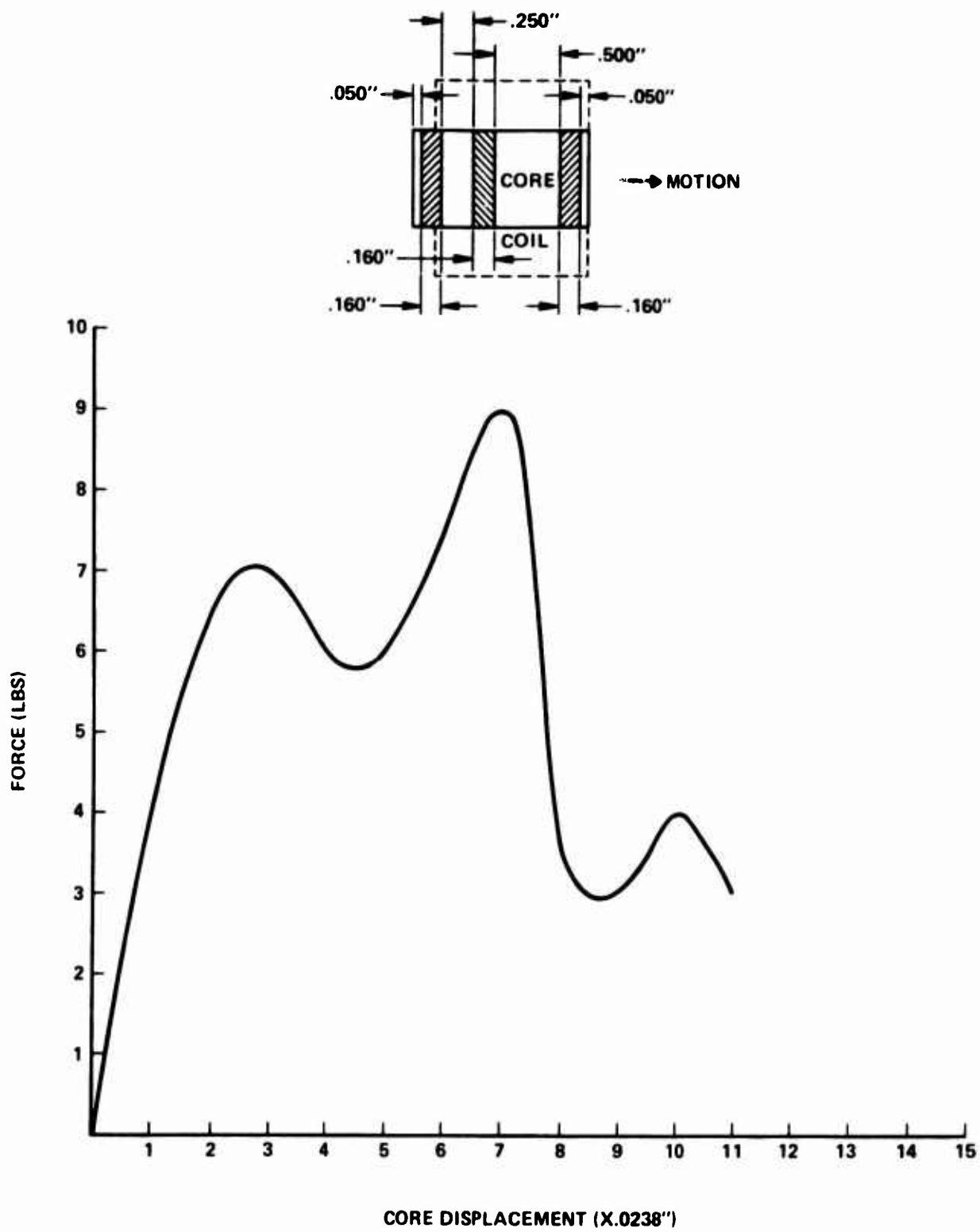
Figure 34. Force-Displacement Plot of Core with Safing Magnet
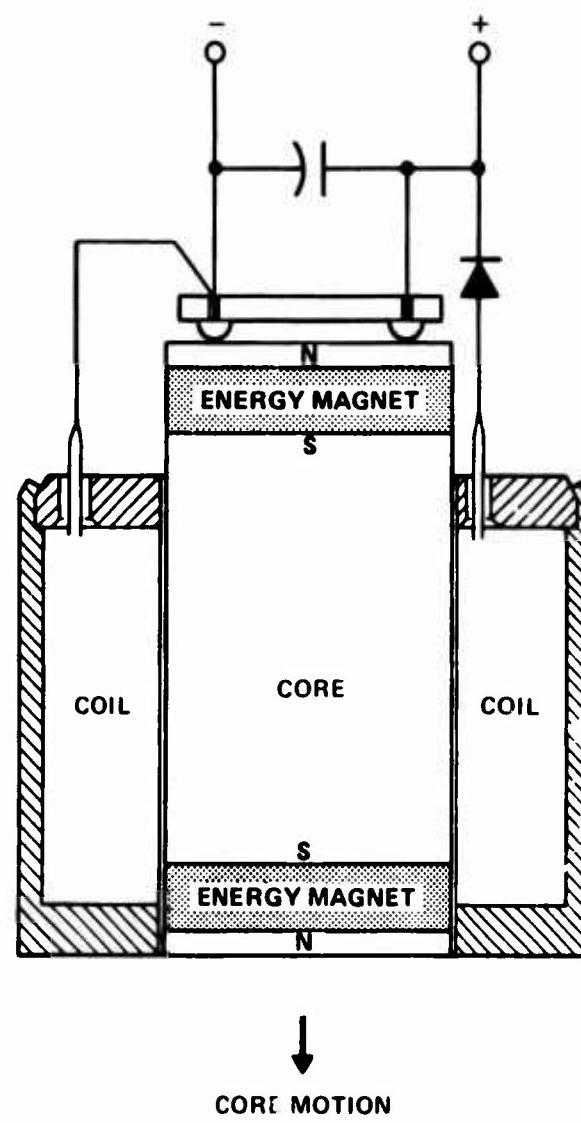
Figure 35. Electrical Safing Feature - Generator Electrically Safe
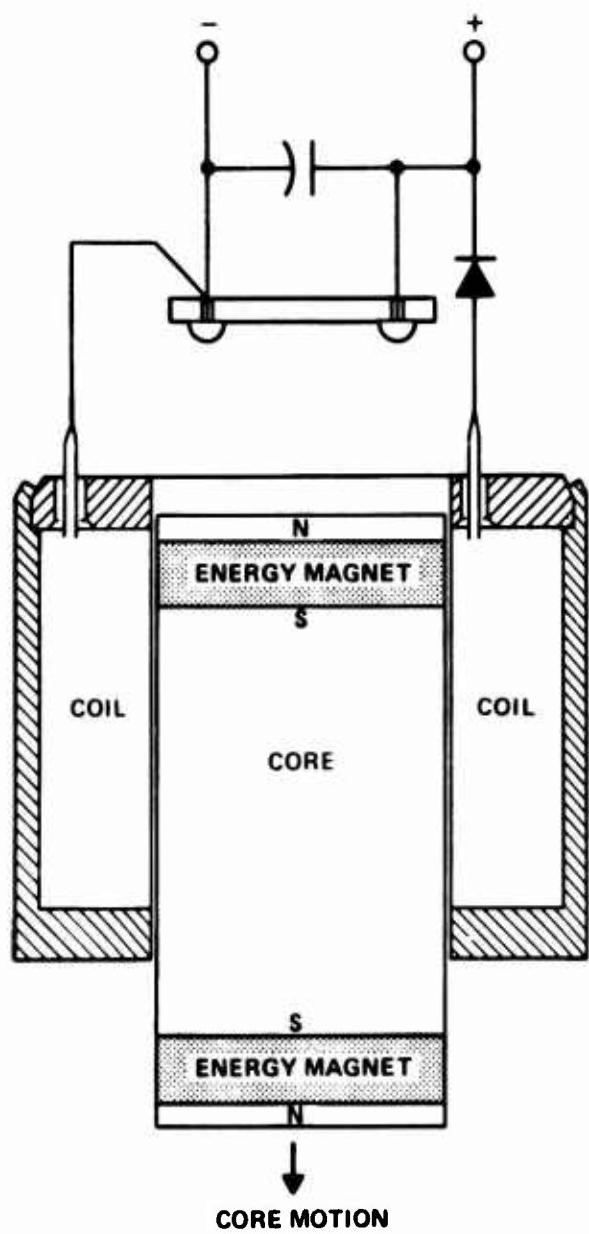
Figure 36. Electrical Safing Feature — Generator Electrically Armed

NORMAL GENERATOR OUTPUT

10 G'S/CM

5 VOLTS/CM

10 MSEC/CM

10 G/CM

5 VOLTS/CM
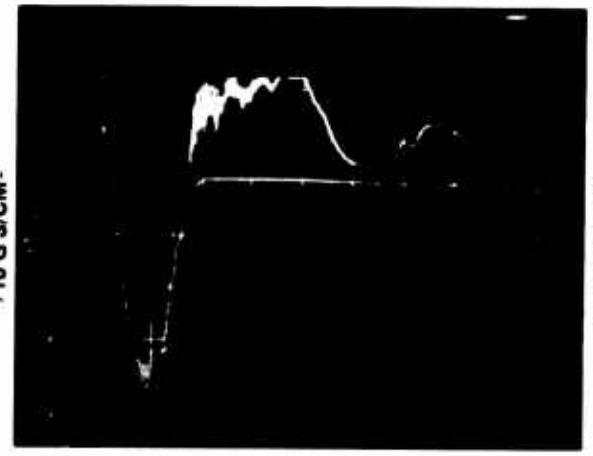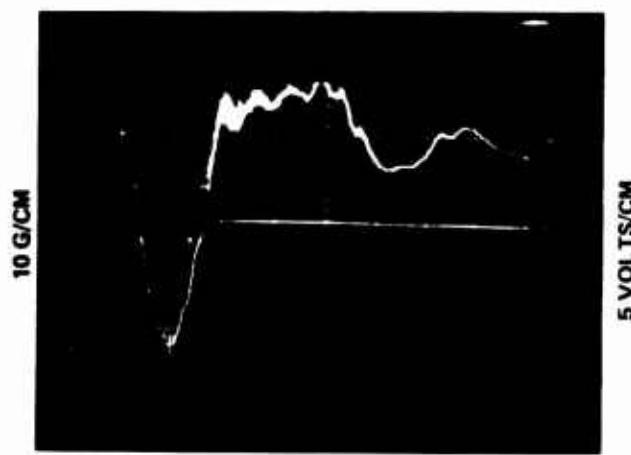
GENERATOR OUTPUT WITHOUT
AUTO-DUMP MECHANISM ENABLED

10 MSEC/CM

GENERATOR OUTPUT WITH AUTO-
DUMP MECHANISM ENABLED.

10 G'S/CM

5 VOLTS/CM

10 MSEC/CM

Figure 37. Generator Output Waveforms Showing Electrical Safing Effect

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15 to 60 g's within a period of 10 to 20 milliseconds. This range corresponded to that which could be expected in a 2.75" rocket launch environment under conditions of both a "hot" or a "cold" rocket motor.

The laboratory test phase provided an opportunity to optimize the generator design prior to fabrication of a larger group of units intended for live launch environment tests.

Range Tests. During a series of live rocket firings conducted at the Camp Edwards Test Range in September of the contract period, a total of 15 rocket launchings were performed in which setback generators were employed as power supplies. A total of eight different generator coils (of three different designs) and six cores (all of the same design) were evaluated. In each case, the energy developed by the generators was impressed upon a capacitor bank consisting of three 150 μf (15 volt) capacitors.

The generators were assembled into plumbing hardware designed to attach to the nose of a rocket as shown in figure 38. Due to the ruggedness of the test hardware and the short range over which these tests were conducted, the generator hardware was found to be easily recoverable for re-test. Data from the generators were recorded via a hard-wire data link

Figure 38. Setback Generator Test Vehicle

between the test package on the rocket and a ground base recorder. Generator output, which peaked at about 20 milliseconds following rocket first motion, occurred at about 5 feet of rocket travel. The rocket was made to impact into a soft sand pile located some 15 feet in front of the rocket launcher. Figure 39 shows the test setup.

Figure 39. Rocket Hardware and Test Setup

Test Results. A sample of the data recorded during this generator test series is reproduced in figure 40. It shows (1) the application of the rocket motor fire signal, (2) motor latch release, (3) rocket first motion, (4) the generator coil voltage trace, (5) the capacitor bank voltage trace, and (6) rocket impact into the sand pit at 174 inches into its trajectory. Note that the coil voltage peaked at about 20 milliseconds following rocket first motion and that the capacitor bank charged to 16.5 volts equivalent to nearly 560,000 ergs of stored energy.

Results of each of the 15 generator test shots are presented in table 1.

It was concluded, on the basis of these test results, that setback generators of the design tested would be suitable for use in the deliverable fuze hardware thus avoiding the use of a less desirable primary cell battery pack as a fuze power source.

The setback generators were subsequently packaged within the deliverable fuze hardware as shown in figure 41. The generator occupied the space within the aft section of the fuze body with the generator core affixed to the fuze base plate. The flexible coil leads were routed through a hole which ran through the center of the core, to the fuze logic module located in an area aft of the fuze body.
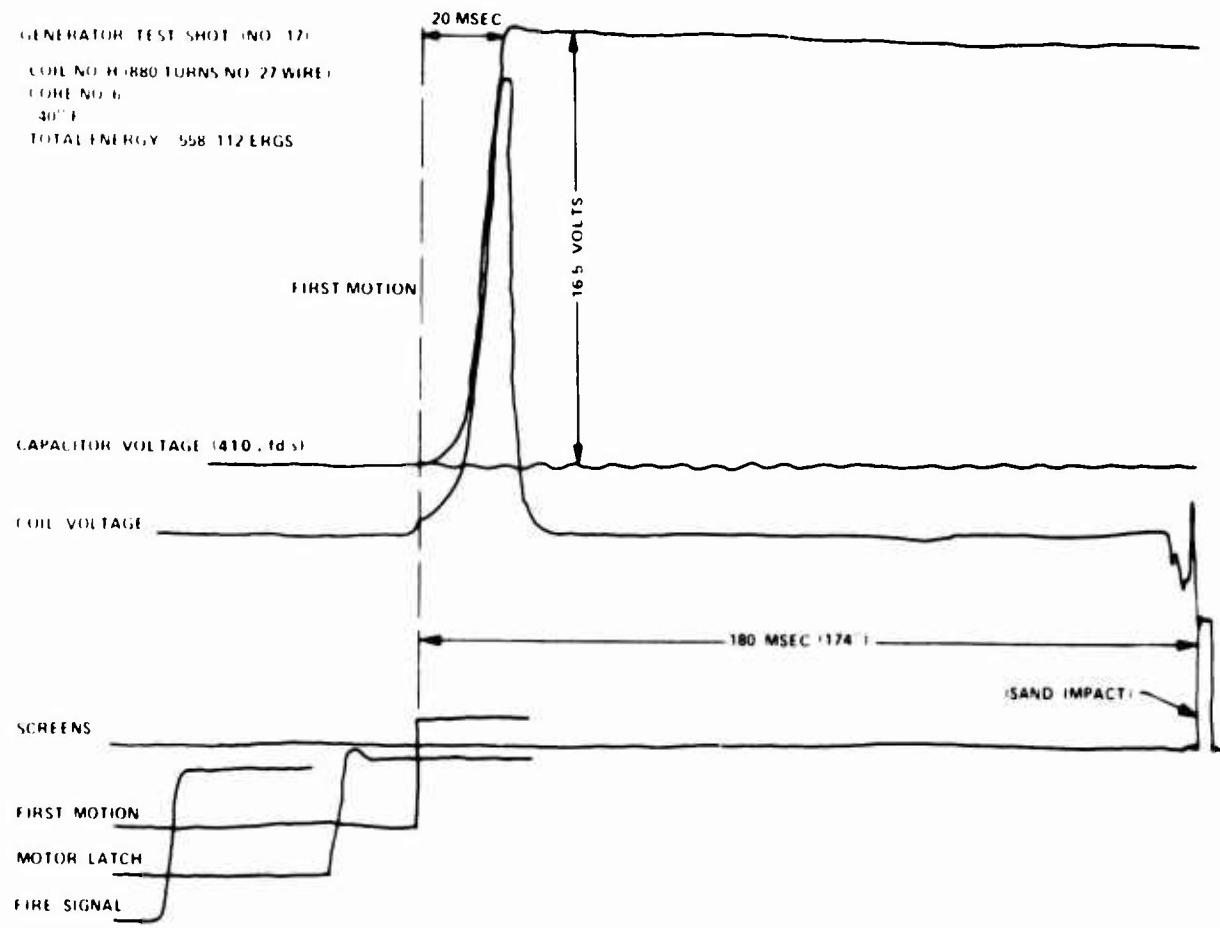
Figure 40. Generator Flight Test Data
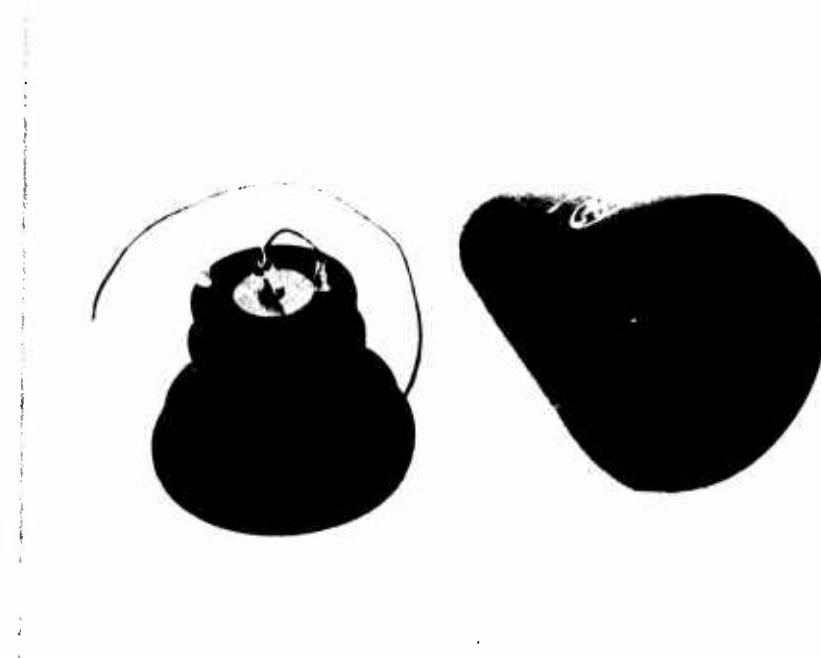
Figure 41. Setback Generator Assembled Within Fuze

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TABLE 1
CAMP EDWARDS TEST SUMMARY

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Date	9/9	9/10										9/11				
Test No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Test Objective	EB→										IB→	Gen→				
Motor Temp.	70°F→				-35°F→							-40°F→				
Warhead Wt. (lbs)	10→															
Motor Latch	In→															
Coil No.												L	L	G	C	J
Core No.												6	6	1	1	2
Coil Preload												–	–	0.1"	–	–
Max. Coil Voltage												1.0	0	9.7	16.5	14.6
Max. Cap. Voltage												0.5	0	10.7	16.0	14.0
Capacitance (μf's)												410	410	410	44	406
Oscillator No.																
T_r→ Osc. Start-up (msec)																
Freq. Stability (%)																
Peak Acceleration (g's)										50+	32.8					
T_f → Peak Accel. (msec)										43	56					
T_{fm} → Peak Accel. (msec)										4	-6					
T_f → T_{lr} (msec)	0	6	28	9	73	46	26	7	47	8	46	55	70	62	106	15
T_f → T_{fm} (msec)			32	20	73	45	33	5	62	39	62	68	82	73	131	59
T_{fm} → 18" (msec)	62															
T_{fm} → 18.5" (msec)		62	51	52	61	74	92	59								
T_{fm} → 48.5" (msec)	93															
T_{fm} → 55" (msec)		102	88	90	97	113	110	132	100							
T_{fm} → 91.75" (msec)	126															
T_{fm} → 90" (msec)		128	114	116	127	142	139	158	128							
T_{fm} → 174" (msec)		179	158	162	173	408	171	172	176	181	179	181	162	152	150	175
T_{fm} → Max. Coil Volt (msec)												10		9	3	26
T_{fm} → Max. Cap. Volt (msec)												10		10	3	26

Notes (vertical, by column):
- Test 12: Coil jammed
- Test 13: Coil jammed
- Test 14: No timing lines on recorder
- Test 16: Coil worked hard prior to firing

CODE:

EB	Exterior Ballistics	a	Estimated value
IB	Interior Ballistics	b	Data taken from T_f not T_m
Gen.	Generator	c	Coil motion erratic
Osc.	Oscillator		
T_r	Reset Pulse		
T_f	Fire Signal		
T_{fm}	First Motion		
T_{lr}	Latch Release		

TABLE 1

	9/11								9/12						9/13						
11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
►	Gen →									Osc	Gen	Osc →	Gen	EB →				Osc	Gen	EB
	−40°F →							+70°F ►		130°F	+70°F ►		+130°F →					+70°F →		
								2.3	10 →											
																				Out
–	L	L	G	C	J	H	L	J	K	J	F	H	L	–	–	–	–	J	E	–
–	6	6	1	1	2	6	3	2	4	2	3	3	2	–	–	–	–	4	5	–
–		–	0.1"	–	–	–							–							
–	1.0	0	9.7	16.5	14.6	17.3	16.0	14.4	16.3	17.7	16.3	16.0	11.4	–	–	–	–	16.2	17.0	–
–	0.5	0	10.7	16.0	14.0	16.5	15.0	13.7	–	17.0			10.4	–			–	–	16.3	–
–	410	410	410	44	406	410	411	409	410	411	406	410	411	–			–	406	400	–
–	–	–							5		3	5	–				–	3	–	–
–									27		18	8					–			–
–											>1%	>1%					–			–
2.8																				
6																	–	47	44	
6																		22		
46	55	70	62	106	15	40	7	29	20	12	27	7	17	20		14	15	19		
62	68	82	73	131	59	58	14	32	22	15	27	21	25	25[a]	0	18	20	25	24	32
–														47[a]	18	51	68	–	–	
–														83[a]	69	86	103		–	127[b]
–														107[a]	129		–		196[b]	200[b]
79	181	162	152	150	175	180	190	218	178	165	166	172	150	149[a]	156	157	172	193		
–	10		9	3	26	20	70[c]	30	25	16	27	17	11						–	44[b]
–	10		10	3	26	20	70[c]	30		16			11							45[b]

Column annotations:
- 12: Coil jammed
- 13: Coil jammed
- 14: No timing lines on recorder
- 16: Coil worked hard prior to firing
- 19: Osc. freq. was not constant
- 22: No osc. output for 54 msec during flight
- 23: Osc. output shorted on trace due to inst. problem
- 24: Power supply shorted at peak voltage point
- 29: Reset diode line found open following test shot

5. PACKAGING AND MECHANICAL INTERFACES

The general configuration of a 2.75" Beehive round consists of (1) a warhead body (canister) filled with flechettes, (2) a base fuze with a pyrotechnic pusher charge, and (3) a plastic dummy nose cone. This arrangement is shown in figure 42. It was the intent of this program to package the remote set fuze components within the envelope presently occupied by the plastic nose cone, such that identical mechanical interfaces would be involved. Figure 43 is a drawing of the nose cone envelope.

Within this envelope it would be necessary to package the entire fuze electronics consisting of (1) power supply, (2) logic and oscillator circuits, and (3) receiver amplifier/detector circuits. No safing and arming package was required in this hardware since no explosive components would be involved in the test hardware.

The component packaging arrangement which first evolved is shown in figure 44. The receiver and antenna circuits were located in the forward portion of the fuze ogive, the setback generator (fuze power supply) was located in the aft section of the fuze, while the logic circuits were contained in the fuze mid-section. Due to the limited space available for the fuze logic circuits, it was necessary to package these circuits on a flexible printed circuit tape which was wrapped around the generator and was attached to the inner wall of the fuze body. Figure 45 is a prototype of this electronics package.

A major concern associated with this design, however, was the sensitivity of the oscillator circuit to de-tuning due to its close proximity to the metal walls of the fuze body. A further concern was that physically smaller (and a greater number of) storage capacitors would be required in this packaging design due to the limited space available. Even though laboratory tests were subsequently performed on these new capacitors which established their insensitivity to mechanical shock, it was decided to revert to the use of the 'proven' Kemet capacitors for the deliverable hardware on this program. The flexible tape electronics package, therefore, was abandoned in favor of a more conventional packaging approach in which the logic components were mounted on a circular printed circuit board and relocated behind the fuze in a separate package, and the power supply capacitors were located on the receiver board within the forward section of the fuze ogive. Figure 46 is a drawing of this arrangement and figure 47 is a photograph of the fuze attached to the signature warhead interface module.

The electrical output from the fuze logic circuits is applied to a "Signature Warhead" described in section III D of this report, and to a telemetry package contained within a section of the (empty) Beehive canister. The telemetry electronics package, patterned after a design utilized in a previous program (DAAA21-73-C-0764), was provided as a GFE item by Picatinny Arsenal. The telemetry antenna for the new package differed, however, in that the

FUZE EXPELLING CHARGE 2200 20 GRAIN FLECHETTES PLASTIC NOSE CONE

PUSHER PLATE ALUMINUM CASE
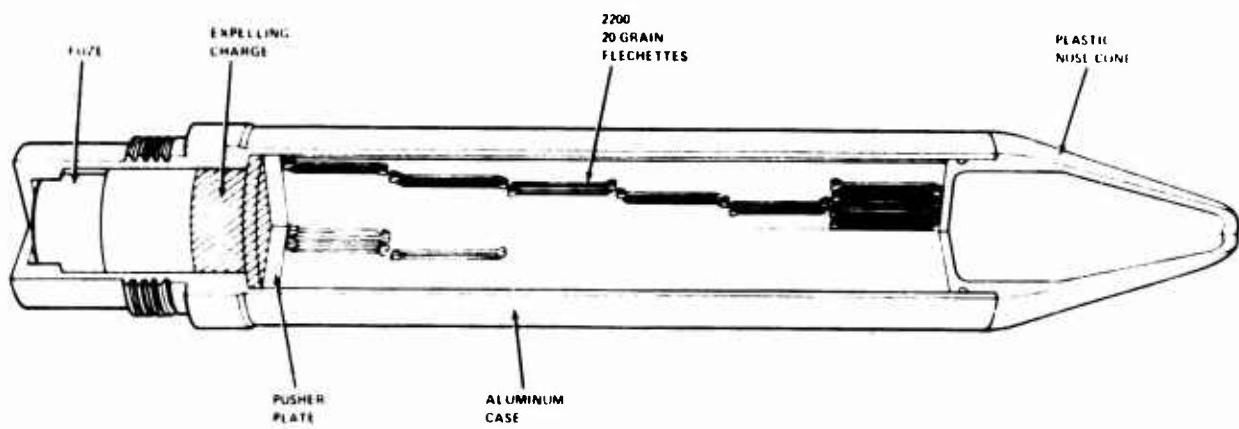
Figure 42. 2.75" Beehive Round Configuration

4.5"

2.75"

FUZE OGIVE

2.75 IN. ROCKET BODY
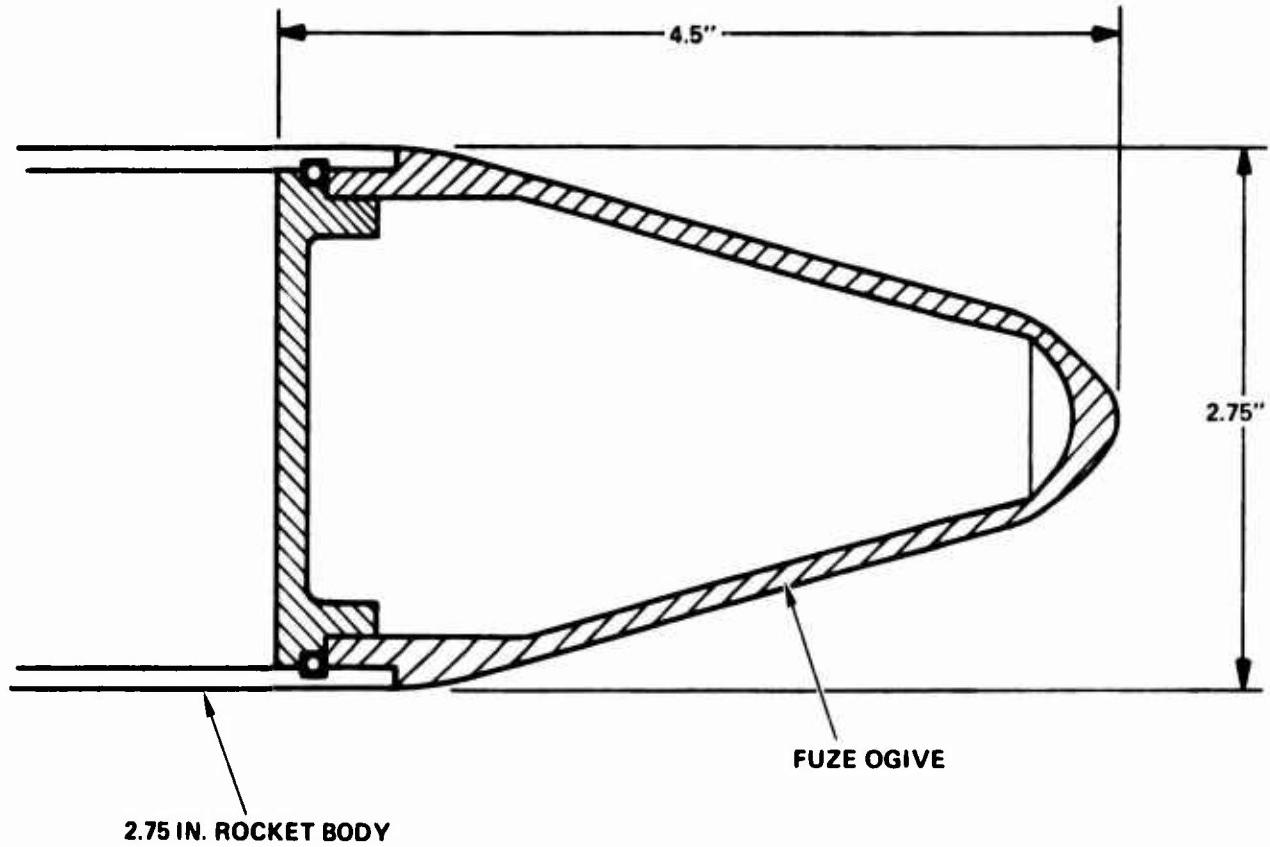
Figure 43. Nose Cone Envelope
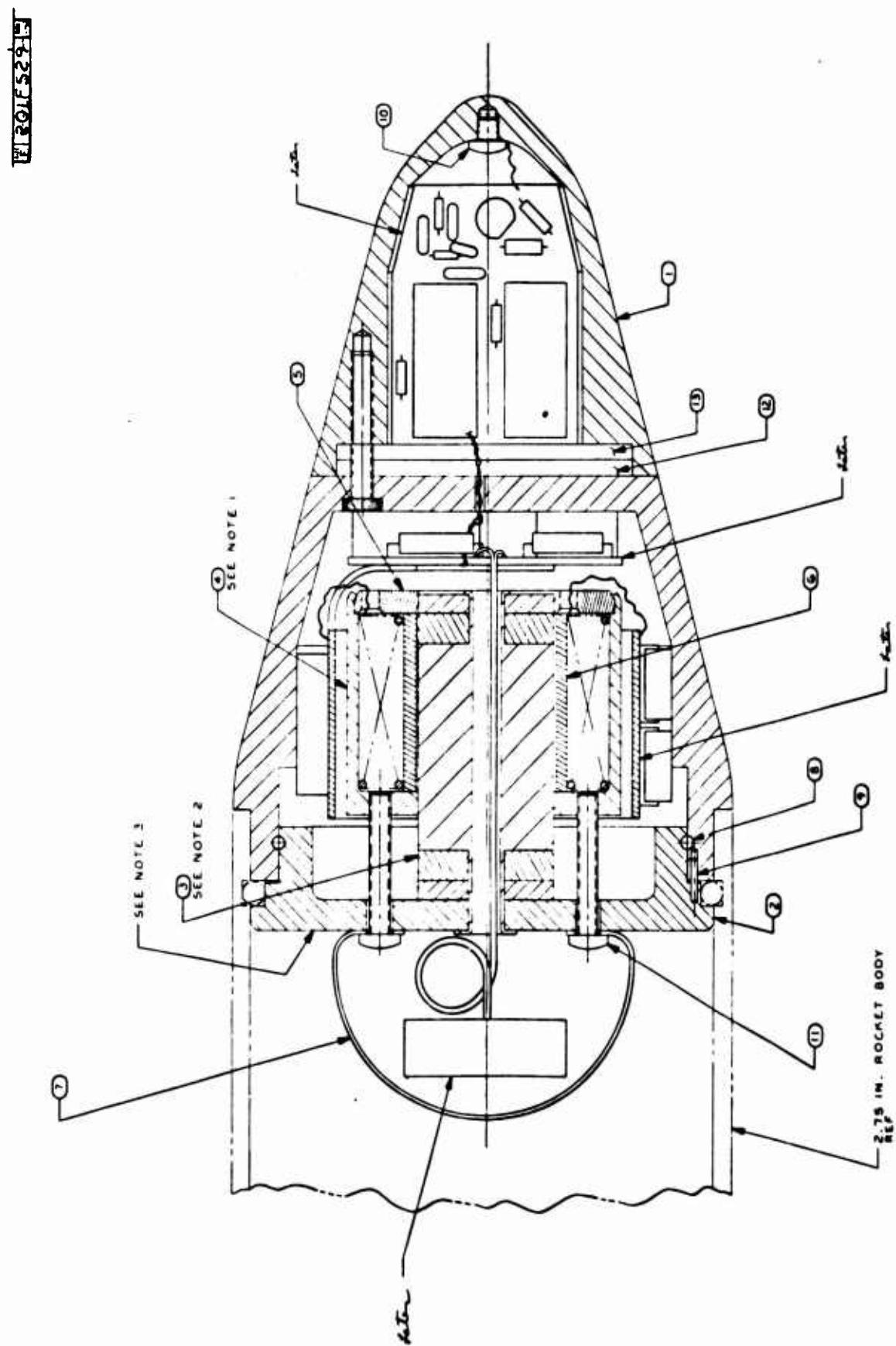
Figure 44. Early 2.75" Rocket Fuze Assembly.
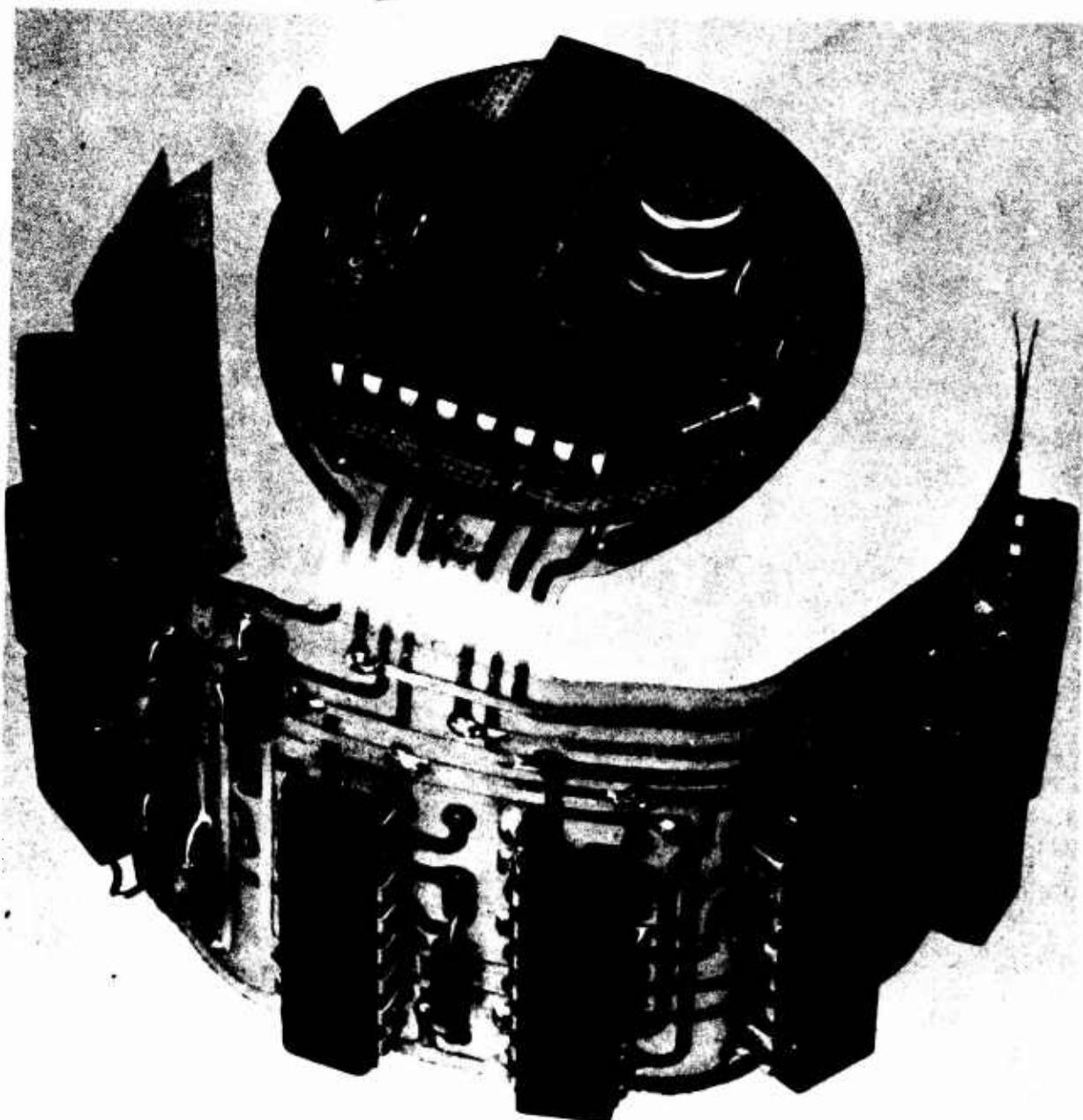
Figure 45. Flexible Printed Circuit Tape Package Design
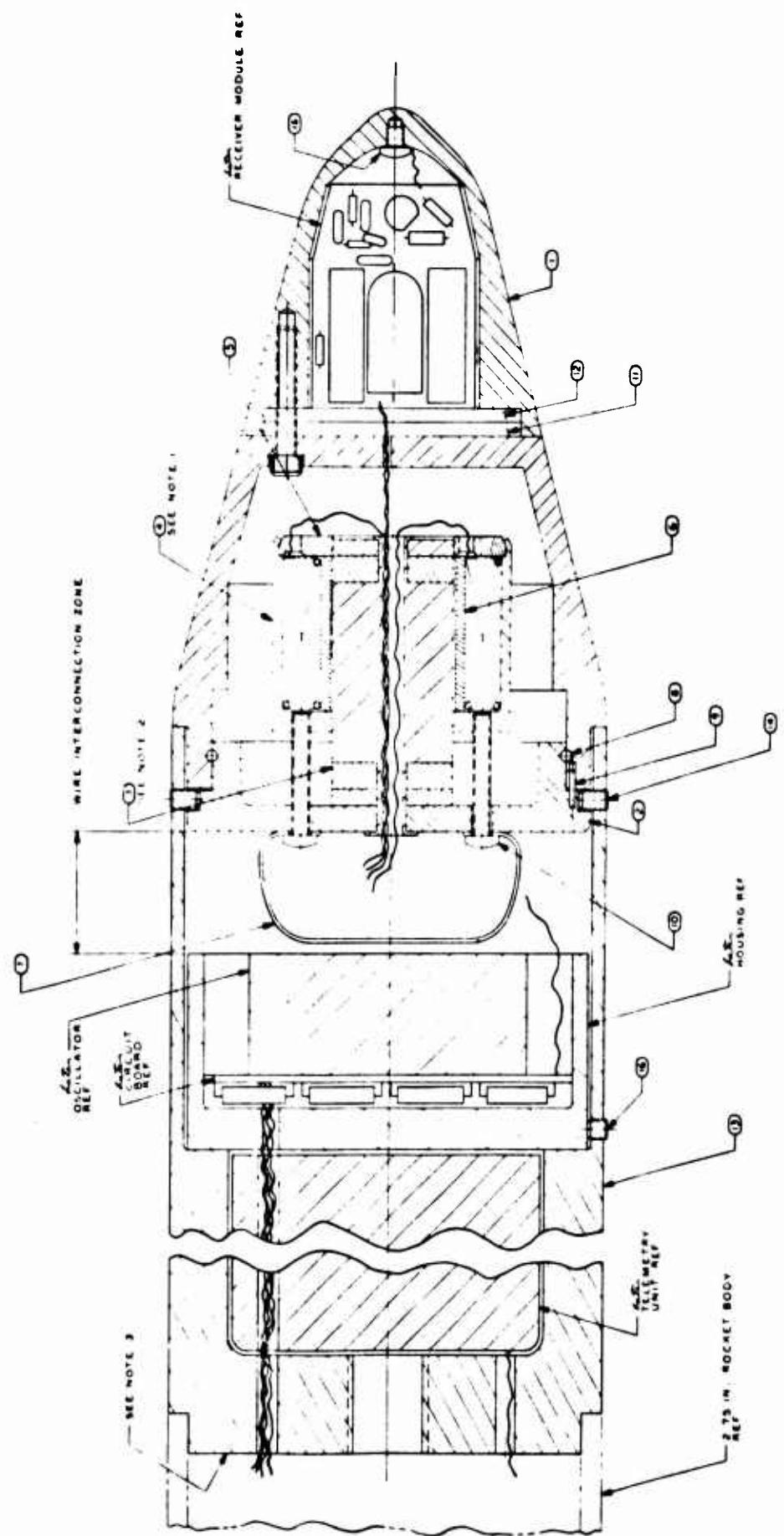
Figure 46. Improved Fuze and Telemetry Package

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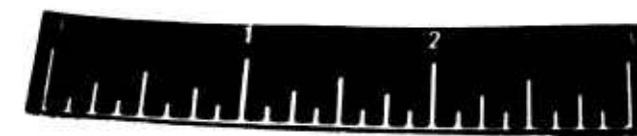
Figure 47. Fuze Attached to Warhead Interface Module

entire rocket frame was utilized as a dipole radiating element rather than relying upon a trailing wire antenna as in the earlier telemetry units. The dipole antenna design was achieved by placing an insulating spacer between the rocket motor and the warhead fuze structure. This produced two metal radiating elements (of approximate equal lengths) into which the telemetry transmitter would feed. See figure 48. The elimination of the trailing wire telemetry antenna would improve the performance of the telemetry system especially during the period of rocket motor burnout. Previous experience with the trailing wire design showed a high probability of wire separation at motor burnout and subsequent loss of transmitted data.
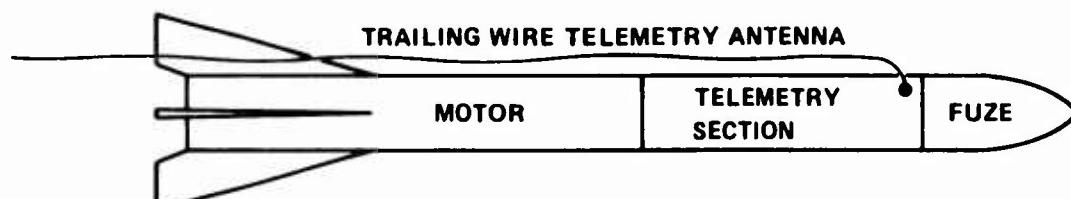
Figure 48. Telemetry Antenna Systems

D. SIGNATURE WARHEAD DESIGN

During the test and evaluation phase of the previous 2.75" rocket fuze program for Picatinny Arsenal (DAAA21-73-C-0764) an inexpensive telemetry module was flown with each fuze test-fired. The purpose of this telemetry unit was to relay, to a ground recorder, the performance of the fuze circuitry while in flight. The telemetry package performed satisfactorily during the early portion of the rocket trajectory (during motor burn) but all communication to the rocket was lost at motor burn-out in each attempt made. The exact cause of this failure has never been clearly identified although the trailing antenna wire attached to the rocket is suspect. In order to avoid a similar problem in the evaluation of the flight hardware on the existing program, it was decided to attach an optical module to the

rocket, the function of which would be to signal desired fuzing events to ground-based recording cameras and/or observers. These signals would be in the form of high intensity light pulses produced from the simultaneous initiation of a bank of five flash bulbs. Three such banks would be packaged into a single module for the purpose of identifying one of three fuzing mode commands (A, B, or C). This module, including its self-contained power supply and drive circuits, is referred to as a "Signature Warhead." It should be noted that provisions have been made in the electronic circuits to also program an electronic telemetry module packaged as a separate unit within the round, if such a data link backup to the signature warheads is considered desirable prior to firing. Picatinny Arsenal has provided these telemetry modules in support of this program.

1. DESIGN

A signature warhead package consists of three banks of five M-3 flash bulbs, each bank containing its individual power supply and drive circuit. A schematic of one flash bank is shown in figure 49. It consists of an 8.4 volt battery which charges three 1000 μf capacitors through an 8g acceleration switch. The acceleration switch will close a few milliseconds
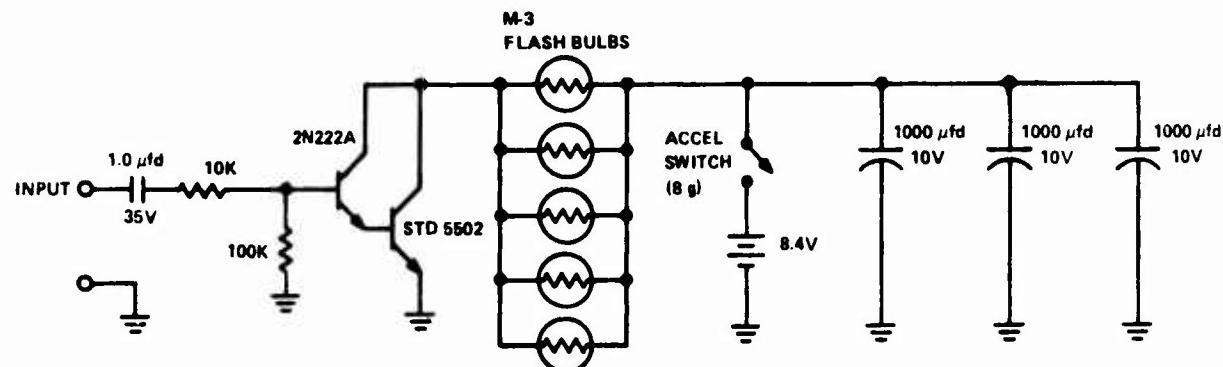
Figure 49. Signature Warhead Schematic

following rocket first motion and remain closed throughout the rocket burn period (approximately 1.5 seconds). The capacitors are fully charged in about 125 milliseconds following the switch closure. The flash bulbs will fire when a fuzing command signal is received on the input line of the Darlington amplifier. A photograph of the components which make up a flash module is shown in figure 50 and a completely assembled signature warhead is shown in figure 51. Note the clear plastic (Lexan) tube which serves to protect the flash modules and also to provide aeroballistically clean lines to the package.
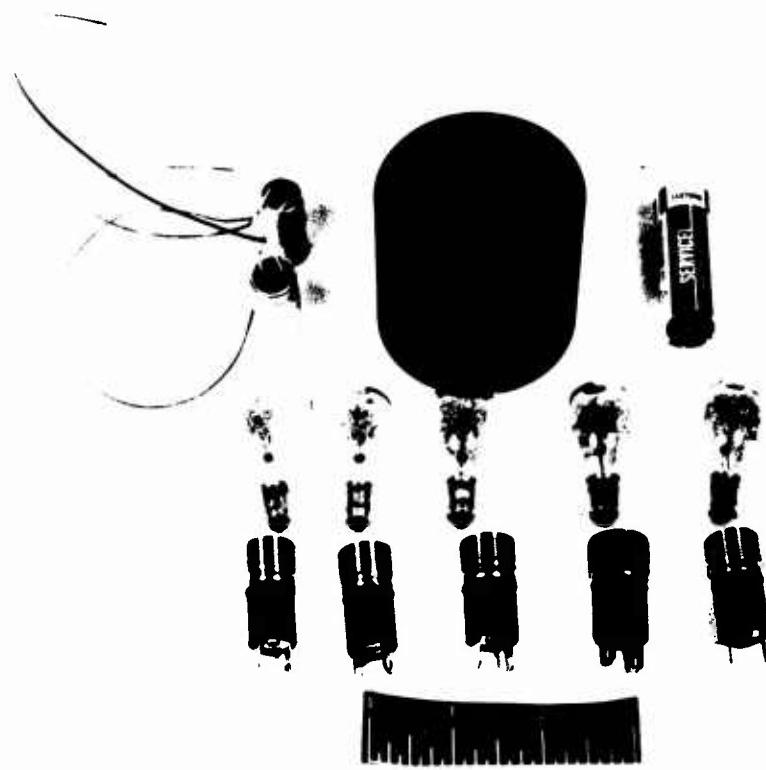
Figure 50. Flash Bank Components

2. TEST FIRING

Early in the program a prototype signature warhead was test fired by Picatinny personnel at Aberdeen Proving Ground to evaluate the light output of the flash units and to assure ballistic stability of the round in flight. This unit contained additional electronics in the form of an analogue timer circuit designed to sequentially initiate the flash modules at 1, 2 and 4 seconds into the flight trajectory.

A schematic of the analogue timing circuit is shown in figure 52. Three such circuits are contained on a single printed circuit board providing output signals at 1, 2, and 4 seconds following rocket first motion. Figure 53 is a photograph of the timer package.

The timing circuit consists of an SR555 analogue timer whose function time is selected by appropriate values of R and C in the circuit shown. Power to the timer is controlled through an acceleration switch activated SCR (not shown in the schematic). The SCR overcomes the effect of contact bounce from the acceleration switch which might otherwise reset the timers during the rocket acceleration period. It also assures that power is applied to the circuit following motor burnout. The negative output signal from the timer (pin 3) is inverted by transistor 2N3390 and applied to one of the flash bulb drive circuits to cause that bank to fire at the selected time along the rocket's trajectory. Camera coverage would normally be used to record the commanded event.

67
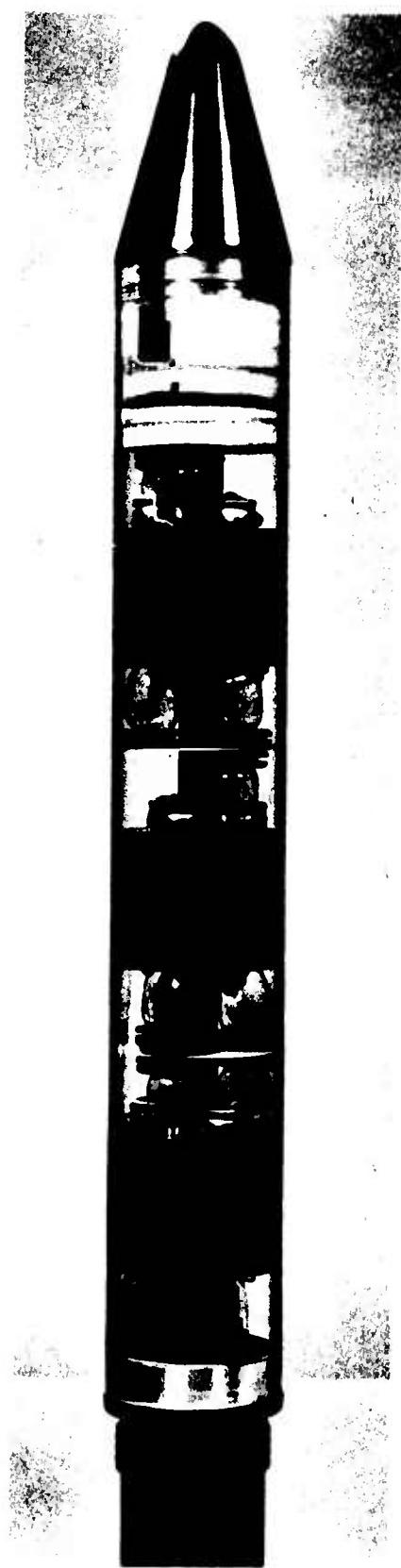
Figure 51. Signature Warhead Assembly
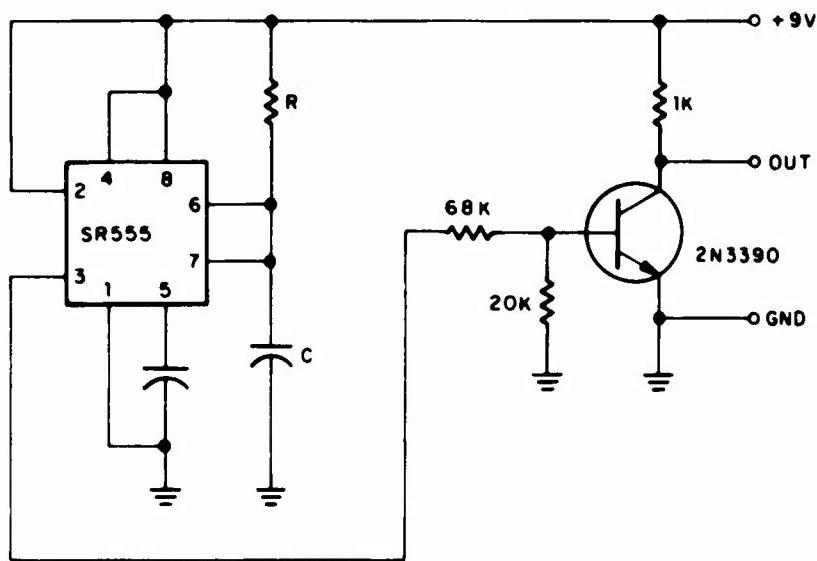
TIME	R	C
1 SECOND	910 K	1 UF
2 SECOND	910 K	2 UF
4 SECOND	750 K	4.7 UF

Figure 52. Analogue Timer Schematic Diagram

Figure 53. Analogue Timer Package

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3. TEST RESULTS

Observers noted that the rocket flew properly during the first 1½ seconds of flight and the first flash module initiated properly at 1.0 second. It was further noted that the flash was easily discernable even though the rocket motor was still burning. At motor burn-out, however, the dummy fuze (plastic) was observed to break loose from the signature warhead section, at which point the rocket went aerodynamically unstable and tumbled into the water. It was not possible to recover the round for examination following the mishap. It is believed, however, had the nose remained secure to the rocket the test would have been successful, since the first flash occurred at the appointed time in the trajectory and it was visible even under motor burn conditions.

Improved fuze attachment features were incorporated into the final hardware design to assure that the test vehicle will remain intact throughout the rocket flight.

E. SYSTEM BENCH TESTS

An "all-up" fuzing system was tested (electrically) using the RST-1 transmitter and multi-mode control unit over a short rf path to the nose assembly (detector and video amplifier) and oscillator/decoder assembly. The waveform in figure 54a shows the (detected) transmitter output pulses of nominal 0.7 and 2.0 microsecond duration. Figure 54b (top) shows the Z5 clocking signal (clocks on trailing edge), while the lower trace shows superimposed wide and narrow pulses on the Z5 data input. The pulse-width discrimination occurs when Z5 clocks are in either a "1" or "0" logic level Figure 54c shows the Z5 clock (upper) and data input (lower) for an entire 10 millisecond receiver window, with the transmitter TCU set for mode 3, 17 pulse data-set. The wide pulses (every third one) can be distinguished by their higher brightness. Note that the clock trace contains 10 pulses, but only 8 after the first wide data pulse, confirming the message format framing action which shuts off the Z4b clock after the first "1" reaches the last (8th) stage in Z5.

Figure 55a shows three waveforms on two time bases. The lower trace (20 millisecond/division) shows the video pulse (green lead) interface. Note the oscillation (at 70 milliseconds) followed by the low pedestal for the rest of the 20 millisecond period. The scope was triggered on the front rather than rear edge of the reset line accounting for the window opening at 70 instead of 60 milliseconds on the scope. As noted before, the video line is activated only for the last half of the receiver-on period, and so ignores the turn-on noise. The top two waveforms show the telemetry lead (upper) and 100 Hz (Z2 pin 4) on a 1 second/division sweep. No rf signal was sent. The output occurred at 5.12 seconds (measured by counter) and the supply voltage is observed to fall from 15 to about 12 volts over the 10-second period, indicating a very wide power margin.

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FIGURE 54a
DETECTED TRANSMITTER OUTPUT

0.5 MSEC/CM

0.5 MSEC/DIV.

FIGURE 54b
Z-5 CLOCKING SIGNAL (UPPER TRACE)
Z-5 DATA OUTPUT (LOWER TRACE)
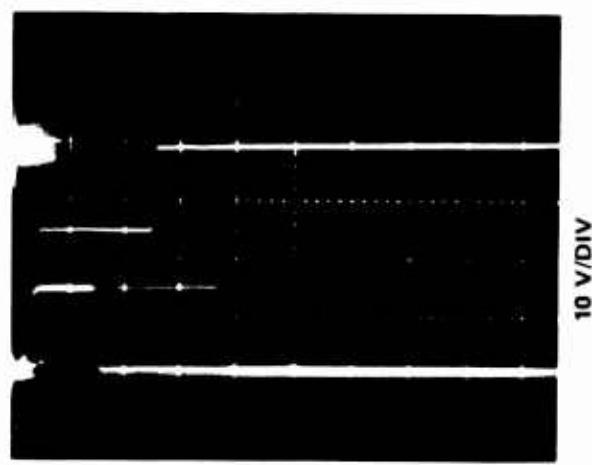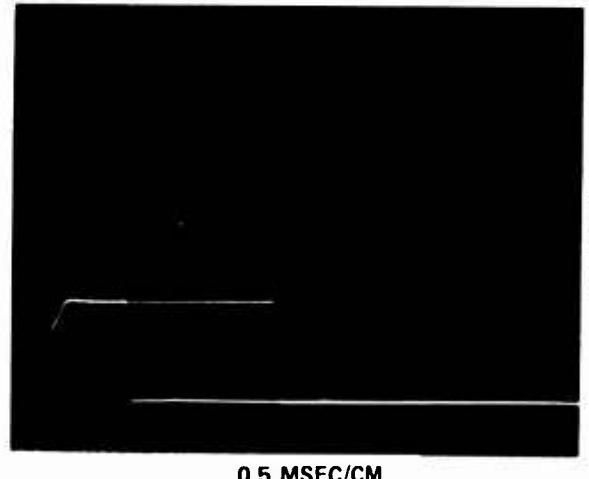
FIGURE 54c
Z-5 CLOCKING SIGNAL (UPPER TRACE)
Z-5 DATA INPUT (LOWER TRACE)
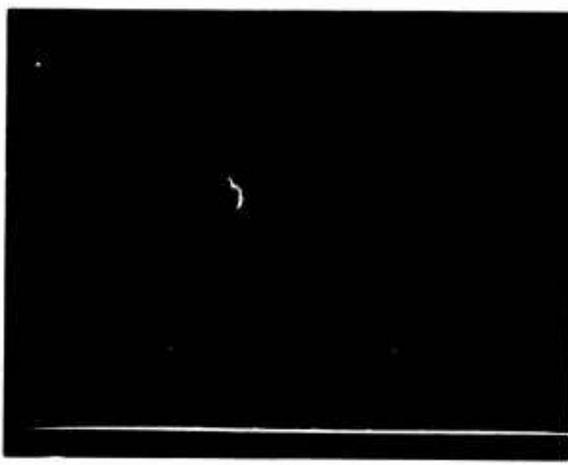
1.0 MSEC/DIV.

Figure 54. Transmitter Output Pulses

FIGURE 55a

MODE I SELECTION

TELEMETRY OUTPUT
(UPPER TRACE)
1 SEC/DIV

VIDEO PULSE TRAIN
(LOWER TRACE)
20 MSEC/DIV
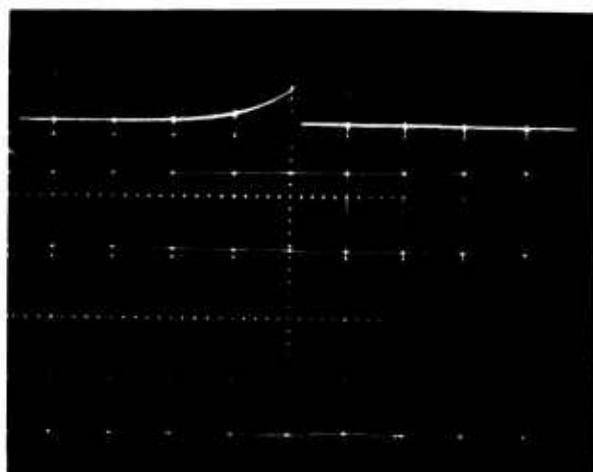
FIGURE 55b

MODE 2 SELECTION

TELEMETRY OUTPUT
(UPPER TRACE)
1 SEC/DIV

VIDEO PULSE TRAIN
(LOWER TRACE)
20 MSEC/DIV

FIGURE 55c

MODE 3 SELECTION

TELEMETRY OUTPUT
(UPPER TRACE)
1 SEC/DIV

VIDEO PULSE TRAIN
(LOWER TRACE)
20 MSEC/DIV
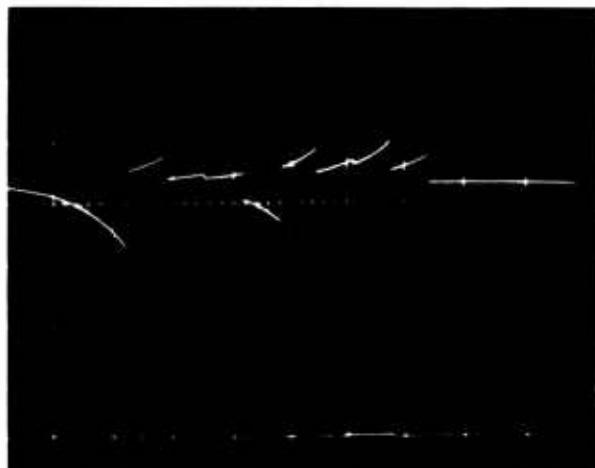
Figure 55. Telemetry Output and Video Pulse Train Traces for Three Selected Modes

The upper trace in figures 55b and 55c shows the telemetry output lead for modes 2 and 3 respectively, with 250 data pulses sent. The first (timed) transition occurs at 2.62 seconds (5.12-2.50), followed 1.28 seconds later by mode 2, or 0.64 and 1.28 seconds later in mode 3. The lower trace (20 millisecond/division) again shows the receiver signal (green) line, where the presence of modulation throughout the 20 millisecond period can now be observed.

Anomalous results were observed when data sets above 400 were used in strong signal conditions. The onset of this effect is instantaneous; i.e., between 400 and 401. We have verified that the transmitter is functioning properly and observe that, at 400 pulses and lower, the minimum pulse spacing is 20 microseconds, while at 401 and up it drops to 10 microseconds. There is apparently an overload recovery problem in the receiver under the 10 microseconds strong signal condition which we haven't noted at 20 microseconds. Since the set time for 400 pulses is 1.12 seconds, well within the (ambient temperature) rocket motor burn period, this should not represent a problem during our range tests. Setting periods shorter than 1.5 seconds will therefore not be attempted. The cause of this receiver overload condition has been identified and will be corrected in the design of any subsequent fuze hardware.

1.   TRANSMITTER OUTPUT POWER VARIATIONS

The RST-1 transmitter was originally designed to operate for a brief data burst, whereas the present modulation requirements result in variation in output power as prf and mode (wide/narrow pulse ratio) are varied. Table 2 below summarizes the pertinent data measured with pulse widths of 0.75 microsecond (N) and 2.0 microsecond (W). The modes are identified by the $(W + N)/W$ pulse ratio, and are for steady-state conditions.

Table 2

Transmitter Power (dBw)

			MODE		
PRF	Data	All N	1 (7/1)	2 (6/1)	3 (3/1)
10.0 KHz	100		15	15	15
50.0 KHz	500		11.5	11.5	11
99.9 KHz	999	9.5	8.5	8.5	8

2.   OSCILLATOR START-UP TIME MEASUREMENTS

As discussed in III C 3, the fast-starting crystal oscillator circuits required individual adjustments, aided by monitoring the period of two nominal 10-millisecond windows and the period of the first 2048 oscillator cycles following removal of the reset pulse, evidenced by

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the transition of the scalers twelfth stage (Q12). The windows all gave the correct period (to within the one count ambiguity) using a 10 microsecond resolution. Figure 56 is a plot of the Q12 period measurements; when a given unit was measured several times, the periods usually matched within a few tenths of a millisecond, so the scatter observed is believed to be either a function of individual circuit variations or the instrumentation techniques employed. In any event, the scatter seems to be negligible compared to rocket ballistics variations.
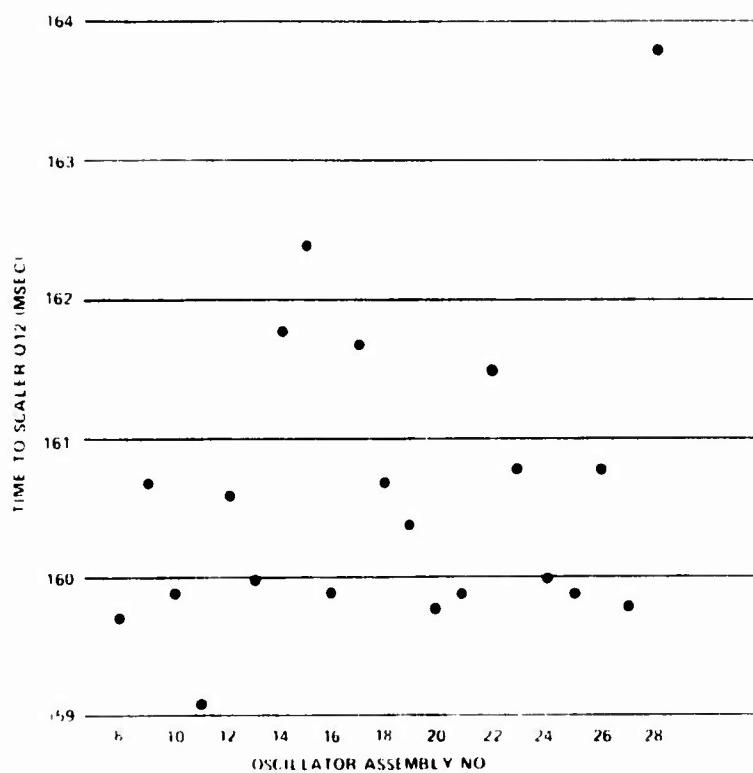
Figure 56. Oscillator Start-up Measurements

3. OSCILLATOR TEMPERATURE TESTING

One oscillator circuit was tested at temperatures from -40 degrees F to +105 degrees F and one unit was tested from -40 degrees F to +190°F. No changes were observed except that one anomalous count was noted on oscillator Number 6 when, after a two-hour soak at +105 degrees F, the early window period measured 10.16 milliseconds. (The later window period was correct at 9.99 milliseconds). The measurement could not be repeated; possible hypotheses include variations in the setback generator waveform (but not elsewhere observed) or just the statistical probability that noise and the free-running oscillator provided a weak excitation of the crystal. Counter thresholds were occasionally a problem, but probably did not enter here.

F. RANGE TESTS

During the week of September 7th an extensive series of tests were conducted at Camp Edwards, Massachusetts for the purpose of evaluating certain components and electronic circuits proposed for inclusion into the deliverable hardware on this program. Specifically, it was the objective of these tests to obtain data on the following:

1. Rocket interior ballistics profile.

2. Rocket exterior ballistics profile during the first 200 milliseconds of free flight.

3. Energy output and voltage waveform of the setback generator power supply.

4. Evaluation of a crystal tuning fork oscillator in a dynamic launch environment.

5. Verification of Signature Warhead function and performance.

1. INTERIOR BALLISTICS

Rocket interior ballistics was measured by means of piezoelectric transducers within rocket test hardware with the data hard-wired to base recorders. This hard-wired data link technique was identical to that successfully employed in previous tests on similar hardware. An example of this hardware is shown in figure 57. Data from these shots showed that the peak acceleration experienced (with a rocket motor temperature of -35°F) is in the order of 35 g's occuring at about 35 milliseconds following rocket first motion. See figure 58.

2. EXTERIOR BALLISTICS

Exterior ballistics testing of the rockets was accomplished by firing the rockets through a series of paper break-wire circuits located at fixed positions along the flight path of the rocket. Five such break screens were located within a space of 174 inches in front of the rocket launcher and the time required for the rocket to reach each screen was measured and recorded from the application of the rocket fire pulse. Figure 59 shows the test setup for these shots. This ballistics data was needed to establish the period of optimum communication to the rocket fuze and the relative location and configuration of the data link transmit antenna. A typical data trace from one such shot is shown in figure 60 and a summary of the recorded data is presented in table 1. A time displacement plot of rocket travel during the first 300 milliseconds of flight, based upon Picatinny Arsenal supplied Hawk radar data, is shown in figure 61. Camp Edwards foil switch rocket data is also shown in the same plot.

75
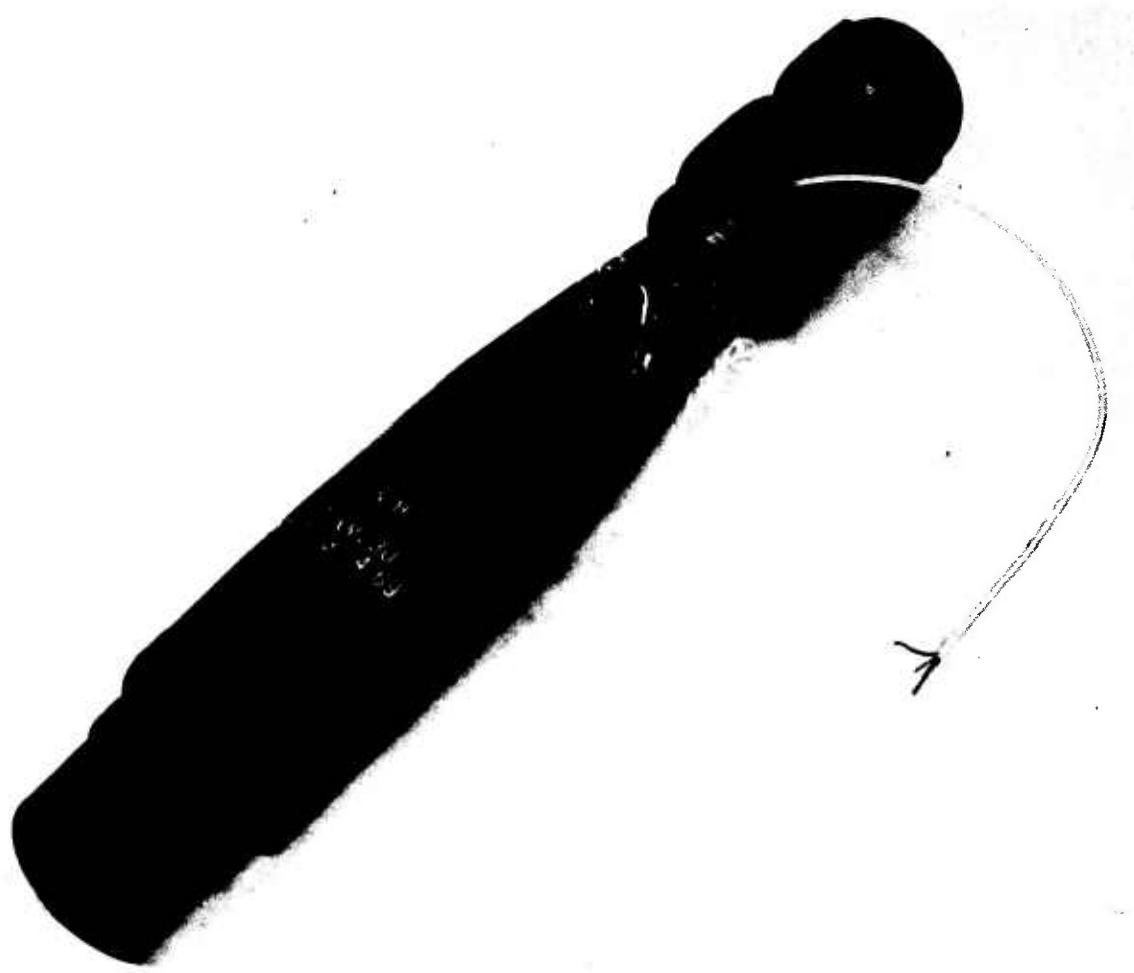
Figure 57. Rocket Test Hardware

——— FIRST MOTION SCREEN

32.8 µs

——— IMPACT SCREEN

——— ZERO G S (REF)

——— MOTOR LATCH SWITCH

——— FIRE SIGNAL
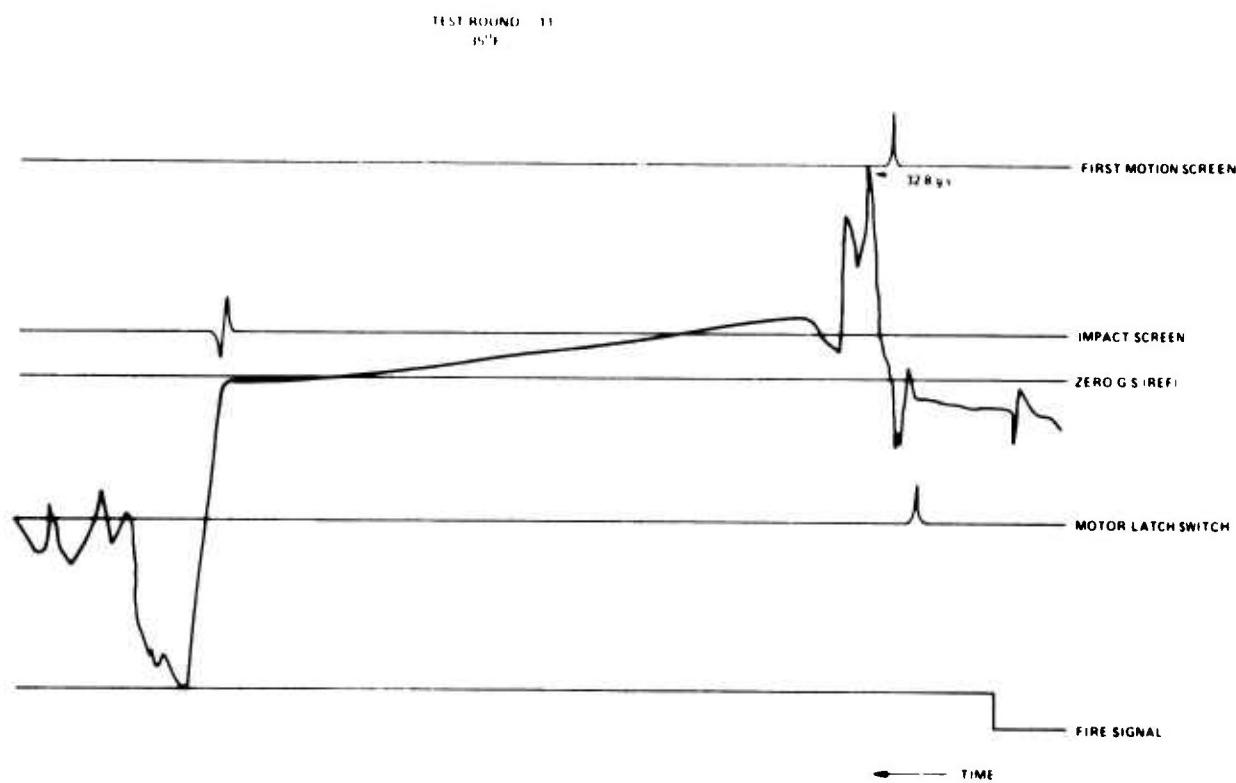
←——— TIME

Figure 58. Interior Ballistics Test Data Plot

Figure 59. Exterior Ballistics Test Setup

EXTERIOR BALLISTICS TEST SHOT (NO. 7)

-35° F

FIRST MOTION

RANGE SCREEN

MOTOR LATCH

FIRE SIGNAL

33 MSEC

23 MSEC

A   B   C   D   E

18.5"(92 MSEC)

55" (110 MSEC)

90" (139 MSEC)

174" (171 MSEC)
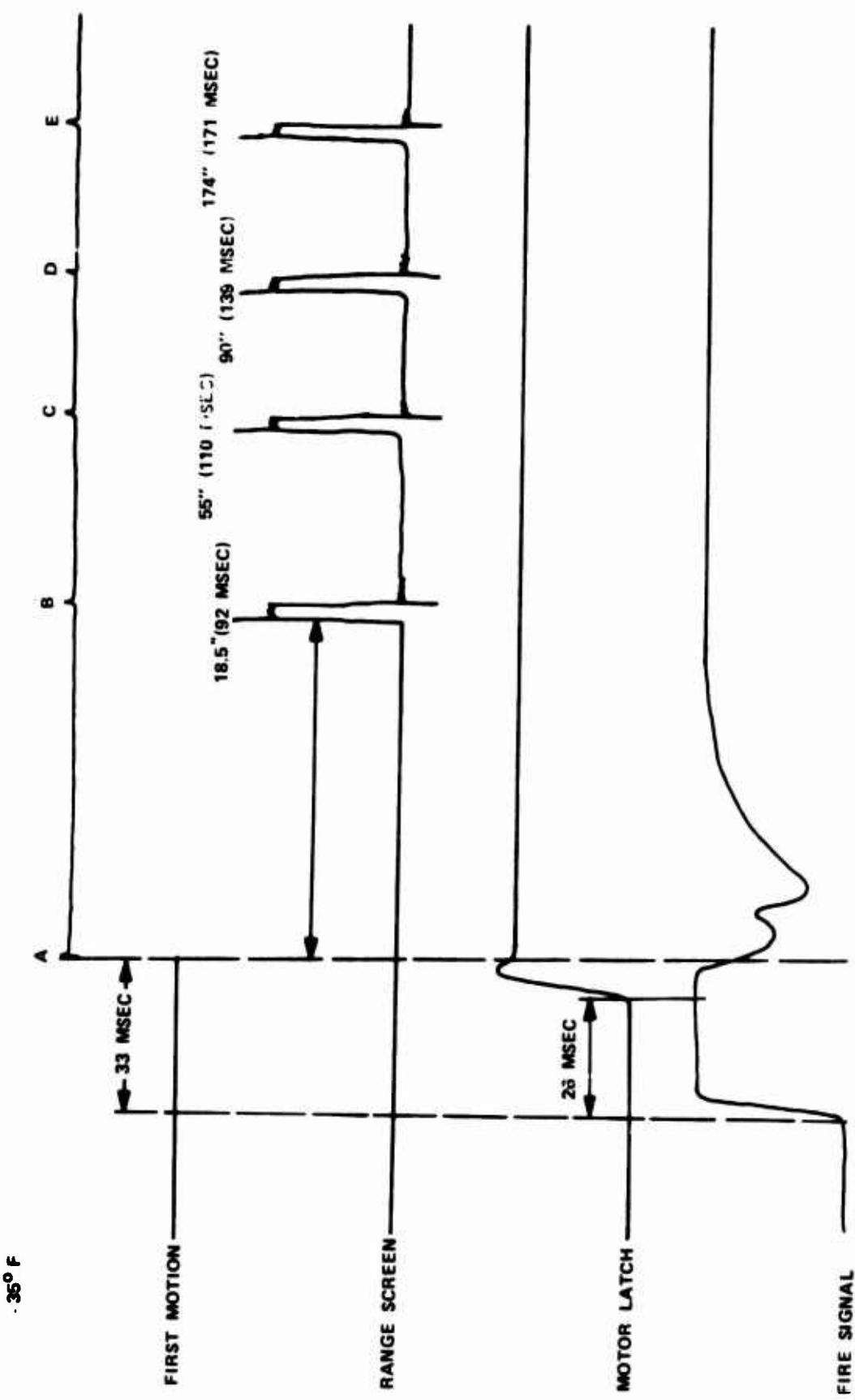
Figure 60. Typical Data Trace - Exterior Ballistics

78
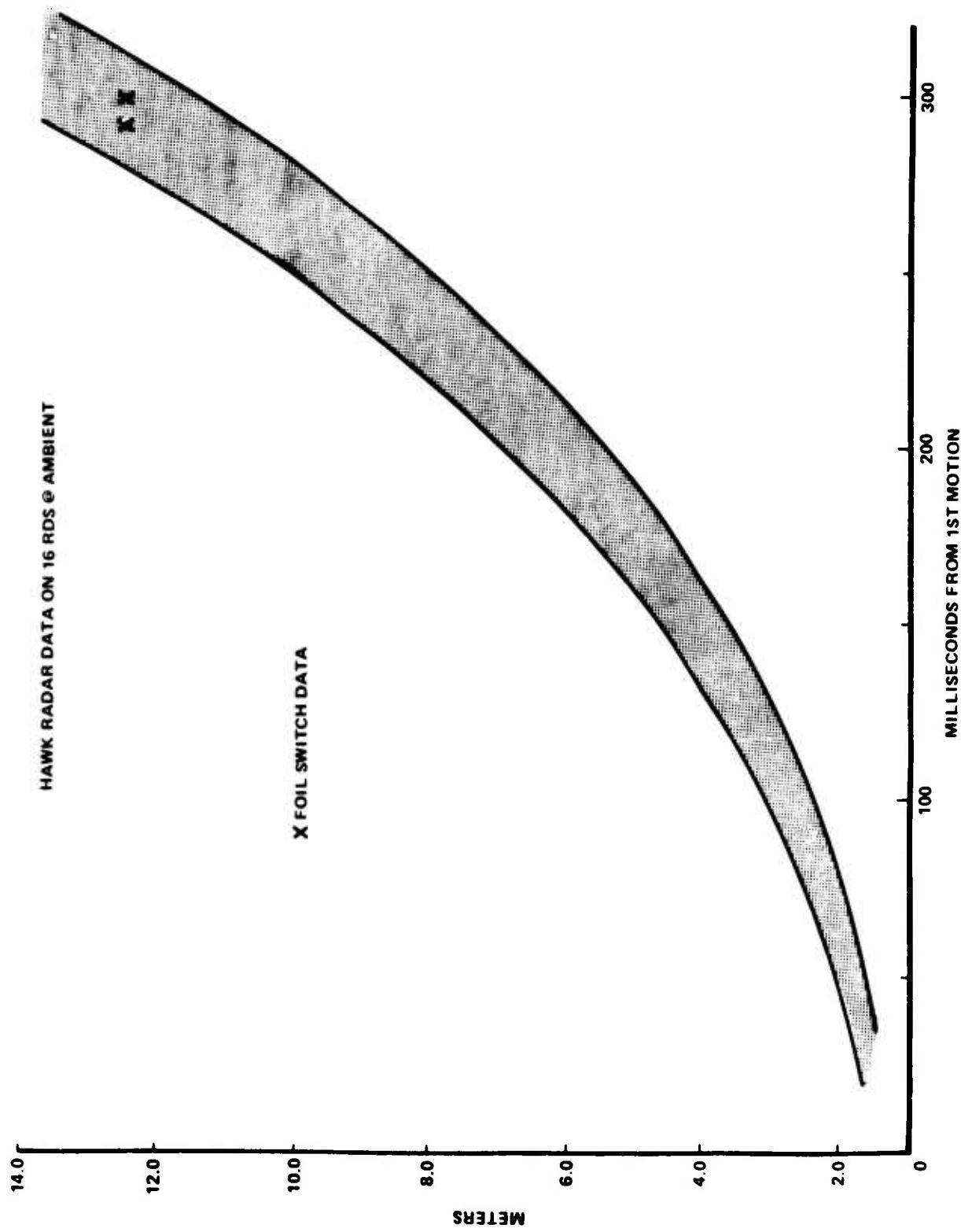
Figure 61. Time-Displacement Plot — Rocket Travel

3. SETBACK GENERATORS

Setback generators were evaluated under conditions of hot and cold rocket motor firings. Previous laboratory evaluation of the generators resulted in an output of about 500,000 ergs for conditions equivalent to an ambient temperature (70°) rocket motor launch. It was important to determine the change in generator output level when fired with a hot or cold rocket motor. Field testing of this effect was necessary since no reliable data on rocket thrust (acceleration) was available for the early burn period of the motors. On the basis of the data obtained as a result of these tests, it is now anticipated the generators will produce about 350,000 ergs of energy during a "cold" launch and about 650,000 ergs during a "hot" launch. This level is more than adequate to operate the fuze circuitry planned for the deliverable hardware on this program. Detailed data and results of these generator test shots are presented in Section III C 4 of this report.

4. CRYSTAL OSCILLATORS

The crystal oscillator circuit proposed for use in the fuze was to be evaluated in a dynamic launch environment in order to ascertain the effects of this environment upon the oscillator start-up time and its frequency stability during this period. Of the four test shots made of the oscillator circuit, only two yielded useful data (see figure 62 a and b) due primarily to instrumentation problems encountered while performing these particular tests. Evaluation of the data available, however, appears to confirm the previously held belief that operation in the rocket environment would not result in a degraded oscillator wave form or a "slow start" time base. Due to the rather inclusive data obtained during these tests, however, it was felt that the oscillators should be further checked in an acceleration environment simulated in a laboratory shock machine. These tests were subsequently performed and the results are shown in figure 63. Note that no discernable degradation in the oscillator waveform results when the unit is subjected to a 40g shock.

5. SIGNATURE WARHEADS

Signature warheads were brought to the test range in anticipation of their being fired and their useful light output monitored at 1, 2 and 4 seconds into the rocket's flight trajectory. Unfortunately, however, the proper range clearance was not available at that time to perform such a test. Rather, the signature rounds were hand carried down range and flashed manually. It was concluded on the basis of these tests that the light output from the rounds would be sufficient to be visible if high ambient sunlight conditions did not exist at the time of firing. Flight evaluation of these rounds was rescheduled and subsequently performed at Aberdeen Proving Grounds. Results of these tests are discussed in Section III D 2 of this report.

OSCILLATOR TEST PATTERN
(PRIOR TO FIRING)

OSCILLATOR NO. 5

100 HZ

12 MSEC

100 HZ OSC OUTPUT

RESET PULSE
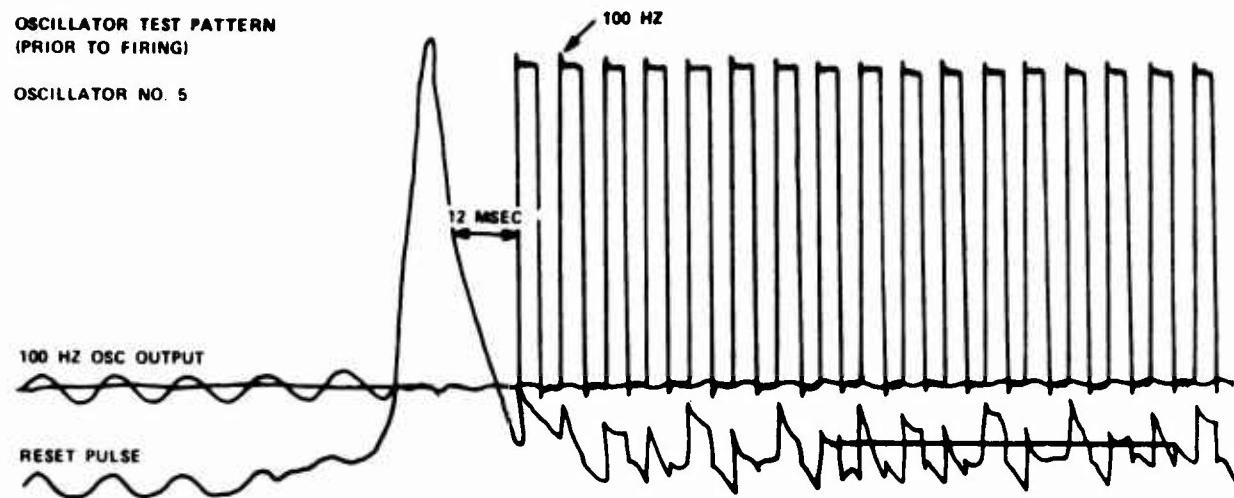
Figure 62a. Oscillator Data Trace

OSCILLATOR TEST SHOT (No. 22)
70° F
OSC NO 3

27 MSEC

16
MSEC

FIRST MOTION

100 HZ OSCILLATOR OUTPUT

RESET PULSE

166 MSEC (174)

FIRST MOTION & 174° MARKER

(SAND IMPACT)

MOTOR LATCH

FIRE SIGNAL
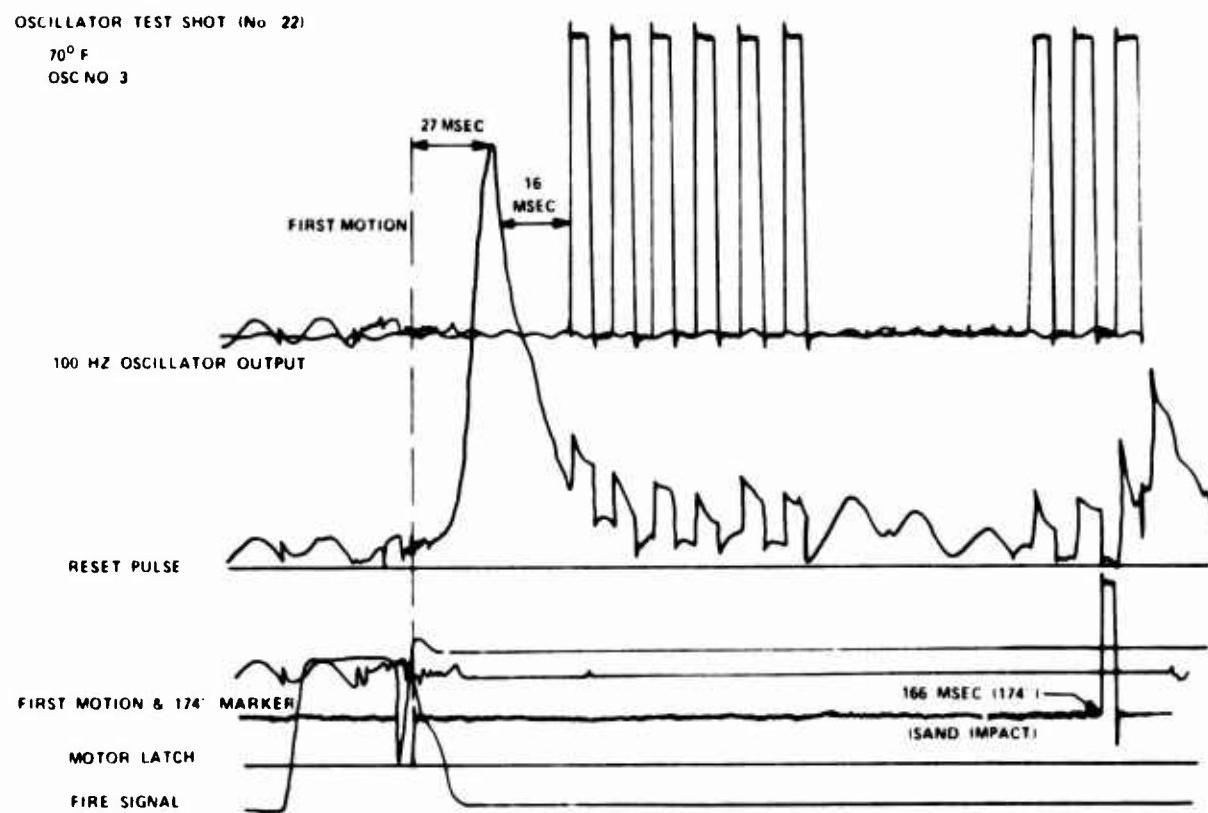
Figure 62b. Oscillator Data Trace

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GENERATOR
RESET
PULSE

5 VOLTS/CM

10 MSEC/CM
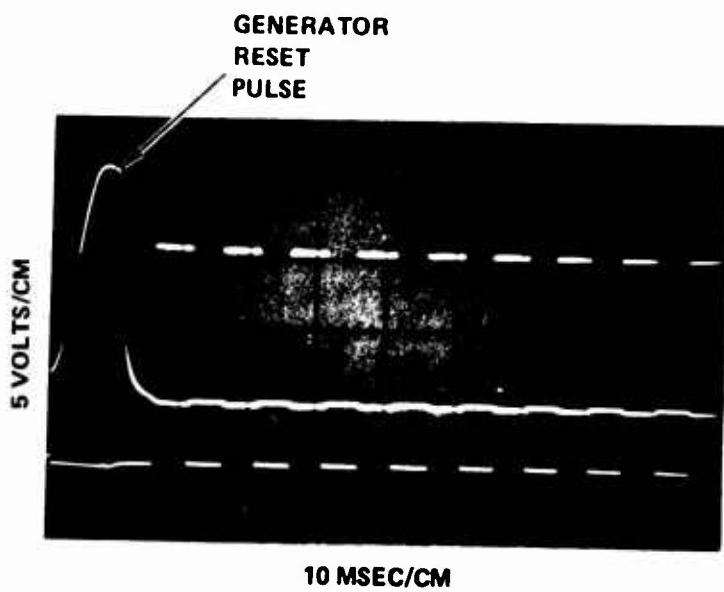
Figure 63 Oscillator Output Trace in Laboratory Shock Environment

Through a combination of range and laboratory tests, all data pertinent to the design of critical components and system communication were obtained and found to be within the limits of acceptability. On the basis of this data, the final design phase of the program was entered into.

SECTION IV
SUMMARY

A. CONCLUSIONS

The principal objectives of this program have been met in that the system study, initiated early in the program, clearly identified a communication technique which, having been reduced to hardware, has been demonstrated to provide an effective multi-option fuzing capability even under the most severe firing rate (salvo) conditions for selected helicopter/2.75" rocket installations.

Laboratory and field tests have also demonstrated that the setback generator power supply and tuning fork oscillator, both designed specifically for use in this fuzing application, represent major advances toward the development of future electronic fuzing systems of an even more sophisticated nature.

The specific accomplishments of this program have been:

1. Performed a system trade-off study to identify an effective data-link communication technique.

2. Modified the RST-1 transmitter to operate in the new "window" communication mode.

3. Implemented a three option, variable time fuze setting technique capable of operation in either single launch or salvo modes.

4. Employed a high energy setback generator as the fuze power supply.

5. Developed a fast start-up tuning fork oscillator for use as the fuze time base generator.

6. Developed signature warheads for use in demonstrating performance of the multi-option fuzes in live firings.

7. Fabricated and delivered to Picatinny Arsenal 15 sets of fuze hardware and a data link transmitter for use in a live firing test of this system.

B. RECOMMENDATIONS

The development of a remote set, multi-option fuzing system can significantly improve the response and effectiveness of present and future armament delivery systems. This program has identified the technology necessary to fully develop such a system and, in addition, has demonstrated an effective implementation of that technology. Design optimization will be required, however, before an operational system can be fielded. It is recommended, therefore, that this development effort be continued and expanded to more fully explore the merits of this system as it applies to advance helicopter armament systems. The General Electric Company would be pleased to participate with Picatinny Arsenal in such a program.

APPENDIX A

ENGINEERING DRAWINGS

DETECTOR CIRCUIT

ANTENNA CAVITY PIN 141

BIAS (YELLOW)

SIGNAL (BLUE)

RCVR

BLACK

GROUNDING SCREW IN NOSE

BUS

SIGNAL (GREEN)

R-OFF (ORANGE)

R-ON (GRAY)

RESET (BROWN)

+V (RED)

GND (BLACK)

YELLOW

BLK

GENERATOR COIL

DECODER

BUSS BAR CONNECTIONS

GND (BLACK)

Q10

Q9

Q8

Q7 (100 HZ)

RESET

+V

GND

OSC / SCALER
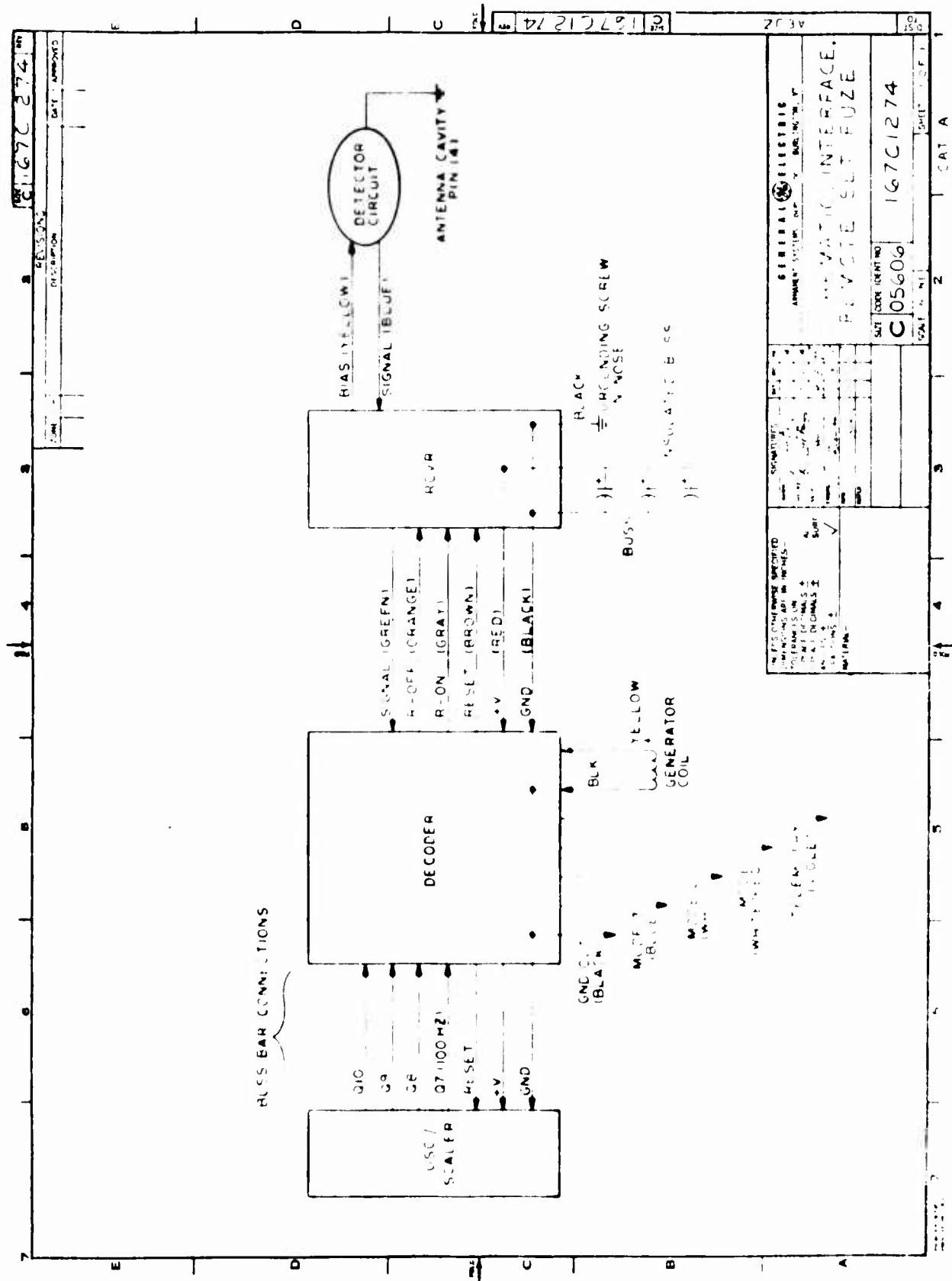
REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED

```
┌──────────┐
│ 100 KHZ  │
│ CRYSTAL  │
│ OSC      │
└──────────┘
     │
     ▼
┌──────────┐      ┌──────────┐    ┌────┐    ┌──────────┐
│ WIDE     │      │ NARROW   │    │ OR │───▶│ LINE     │
│ PULSE    │      │ PULSE    │───▶│    │    │ DRIVER   │
│ DMV      │      │ DMV      │    └────┘    └──────────┘
└──────────┘      └──────────┘                   │
     │                                           ▼
     │                      ┌─────┐        MODULATING
     │                      │ AND │        SIGNAL TO
     ▼                      └─────┘        TRANSMITTER
┌──────────┐      ┌──────────┐
│ RATE     │      │ MODULO   │
│MULTIPLIER│─────▶│ M        │
│          │      │ COUNTER  │
└──────────┘      └──────────┘
     │                 │
     ▼                 ▼
    S3                S2
MANUAL SET           MODE
  1-999              SELECT
```

SCHEMATIC DIAGRAM,
OSCILLATOR

GENERAL ELECTRIC

D | 05606 | 132D1298

OSCILLATOR
CIRCUITRY
TEST CIRCUITRY
REF

CD 40 40 AE

100 HZ
Q12
B 110-120 MS
A 70-80 MS

GRD RESET
10K

R3 10K
R2 330K
R1 1.5M
R5 22M

C5
C4
C3
C2
C6

NOTES:
1. ITEM 2 TO CONSIST OF 880 CLOCKWISE TURNS, WOUND USING ARMSTRONG A12 TO BOND THE TURNS.

5.00
MIN
2 PLACES

.940 MAX
APPLIES TO
ITEM 2

1.360 DIA
MAX

SEE NOTE 1

REVISIONS
ZONE | LTR | DESCRIPTION | DATE | APPROVED

GENERAL ELECTRIC

ITEM NO	ZONE	DWG CODE	IDENTIFICATION NO	DESCRIPTION/ NOMENCLATURE	CODE IDENT NO	QTY	U/M	PC
						1		
				WIRE		AP		

MAKE BY	APPROVALS	CONTRACT NO	PARTS
ISSUED			

NOTES:

1. MATERIAL: GLASS FILLED DIALLYL
   PHTHALATE RESIN, MIL-M-14 TYPE SDG-F.

2. ANSI Y14.5-66 AND 304A835 APPLY.

.730 ±.003 DIA

.95 ±.01

.844 ±.005 DIA

PART NO. 196B7160

GENERAL ⊛ ELECTRIC
ARMAMENT SYSTEMS DEPT LOC BURLINGTON, VT.

FORM, COIL

SIZE	CODE IDENT NO	
B	05606	196B7160

SCALE 2/1   SHEET 1 OF 1

CAT. A

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON

FRACTIONS DECIMALS ANGLES
±   ±   ±

ALL SURFACES 125√

MATL.   SEE NOTE 1

SIGNATURES
DRAWN
CHECKED
ISSUED
ENGRG
MFG
MATLS

REVISIONS
ZONE	LTR	DESCRIPTION	DATE	APPROVED

196B7160

AEJZ   MFI

GENERAL ELECTRIC

				DEPT						LOCATION

TITLE _____

CO IDENT NO ___

PL ___ | **SH NO** | **CONT ON SHEET** | **REV** |

DRAWING CODES
1 VENDOR ITEM · SPEC CONT DWG
2 VENDOR ITEM · SOURCE CONT DWG
3 ALTERED OR SELECTED PT

FOR GE USE ONLY
4 SHORT FORM DWG
5 INSEP ASSY
6 MTCHD PT
7 CUST FURN PT

UNIT OF MEASURE CODES
0 GRAMS 5 SETS
1 PIECES 6 OUNCES
2 FEET 7 INCHES
3 POUNDS 8 PINTS
4 GALLONS 9 OTHER

REVISION CODES
1 ITEM ADDED 4 IDENT NO CHGD 6 EDIT CORRECTION
2 ITEM DELETED 5 IDENT NO. AND
3 QTY CHGD QTY CHGD

ITEM NO	ZONE	DWG CODE	IDENTIFICATION NO.	DESCRIPTION/ NOMENCLATURE	CODE IDENT NO	QTY	U/M	REV CODE
1			12 ___ 29-1	RING, END		1	1	
			___ 49-2	RING, MAG ___		2	1	
			12 ___ 29-3	SECTION ___		1	1	
			___ 29-4	R ___				

SYM	REVISIONS			

MADE BY ___

ISSUED 3-14-75

APPROVALS

CONTRACT NO NEJZ

PARTS LIST FOR 12 D123-7

CONT ON SHEET ___ **SH NO** 1

AEJZ

B 196B7155

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED

.920

.125 ± .010 DIA
⊕ | A | .010 DIA

SEE NOTE 3
FAR SIDE

PART NO. 196B7155

GENERAL ⊛ ELECTRIC
ARMAMENT SYSTEMS   DEPT   LOC BURLINGTON, VT.

HOUSING, OSCILLATOR

SIZE	CODE IDENT NO	
B	05606	196B7155

SCALE 1/1 | SHEET 1 OF 1

CAT. A

.125 ± .005

.062
± .005 R

.06 ± .01

VIEW A
SCALE: 2/1

2.47 ± .01 DIA

SEE VIEW A

.95 ± .01

1.20
± .01

2.56 ± .01 DIA
-A-
2 PLACES

UNLESS OTHERWISE SPECIFIED			DIMENSIONS ARE IN INCHES
TOLERANCES ON			
FRACTIONS	DECIMALS	ANGLES	
±	±	±	
ALL SURFACES	125√		
MATL			

SEE NOTE 1

SIGNATURES

NOTES:

1. MATERIAL: AL ALLOY: QQ-A-225/8
   (6061) TEMP T6.

2. ANSI Y14.5-66 AND 304A835 APPLY.

3. MARK "05606-196B7155" PER 304A843.

94

ADAPTER, FUZE

PART NO. 125C3934

GENERAL ELECTRIC
ARMAMENT SYSTEMS DEPT. BURLINGTON, VT.

SIZE C | CODE IDENT NO. 05606 | 125C3934
SCALE 1/1 | SHEET 1 OF 1

NOTES

1. MATERIAL AL ALLOY QQ-A-225/8
   N6061 TEMP T6
2. ANSI Y14.5-66 AND STANDARDS APPLY.
3. MARK "125C3934" PER 30468.

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED

.562
2 PLACES

.112-40UNC-2B
2 HOLES EQ SP
⊕|A|.015 DIA

1.180 ±.002

.105 ±.002

1.375 ±.002 DIA
-A-

1.430 ±.002 DIA

1.500 ±.003 DIA

.125 ±.003

.740 ±.003 DIA

NOTES:

1. MATERIAL: STEEL: CARBON QQ-S-691
   1070-1090.

2. ANSI Y14.5-66 AND 3M4689 APPLY.

3. FINISH PHOSPHATE COATING 3.1.1.2 OR
   3.1.2.2 OF MIL-STD-171.

PART NO. 167C1116

GENERAL ⊕ ELECTRIC
ARMAMENT SYSTEMS DEPT.   LCC   BURLINGTON, VT.

HOUSING, CORE

SIZE	CODE IDENT NO.		
C	05606	167C1116	
SCALE 8/1		2	SHEET 1 OF 1

SEE NOTE 1

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON:
2 PLACE DECIMALS ±
3 PLACE DECIMALS ±
ANGLES ±
FRACTIONS ±
MATERIAL-

CAT. A

PART NO 132D1240

CAP, BASE, FUZE

132D1240

SEE NOTE 1

.881.01 DIA

5±2
2 PLACES

.144±.001 DIA
2 HOLES 12 AP

1.160

PARTIAL SECTION A-A
SCALE 10/1

NOTES
1. MATERIAL AL ALLOY QQ A 225/6 OR QQ A 200/11
2. ANSI Y14.5 R0 AND 1044B1A APPLY
3. MARK 05606 132D1240F PER 1046B61

NOTES:

1. MATERIAL: STEEL, CARBON, SPRING
   QQ-W-470 (MUSIC WIRE).

2. ANSI Y14.5-66 AND 304AD35 APPLY.

.045 DIA STK

.15 ± .01

PART NO. 196B7184

SIGNATURES			
DRAWN			
CHECKED			
ISSUED			
MATLS			

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON

FRACTIONS DECIMALS ANGLES
± ± ±

ALL SURFACES 125/

MATL.

SEE NOTE 1

GENERAL ⊛ ELECTRIC
ARMAMENT SYSTEMS DEPT LOC BURLINGTON, VT.

PIN, STRAIGHT

SIZE	CODE IDENT NO	196B7184
B	05606	

SCALE 10/1   SHEET 1 OF 1

CAT. A

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED

196B7184   SHEET 1 OF 1

AE12

B 196B7164

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED

.620

.453

.090 ± .003 DIA
₤ CSK 82° ± 1°
X .130 ± .005 DIA
FAR SIDE
2 HOLES
⊕ | A | .008 DIA

30° ± 1°

.740 ± .003 DIA

.125 ± .003

.050 ± .003

⊕ | A | .008 DIA

1.425 ± .002 DIA
-A-

NOTES:
1. MATERIAL: STEEL: CARBON QQ-S-631, 1020-1030.
2. ANSI Y14.5-66 AND 304A835 APPLY.
3. FINISH PHOSPHATE COATING 5.3, L2 OR 5.3.2.2 OF MIL-STD-17L

PART NO. 196B7164

GENERAL ⊛ ELECTRIC
ARMAMENT SYSTEMS DEPT   BURLINGTON, VT.

RING, END

SIZE	CODE IDENT NO	
B	05606	196B7164

SCALE 2/1   SHEET 1 OF 1

CAT. A

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON

SIGNATURES

ALL SURFACES   125/

MATL.

SEE NOTE 1

132D1287

NOTES:
1. MATERIAL: GLASS FILLED DIALLYL PHTHALATE RESIN, MIL-M-14 TYPE SDG-F
2. ANSI Y14.5-66 AND PHASES APPLY

2.45 ± .01 DIA

.10 ± .02

.790 ± .005 DIA
⊕ |.01| .005 DIA

.55 ± .01 DIA

.725
2 PLACES

.363
4 PLACES

.225 ± .005 DIA
x .50 ± .02 DEEP
⊕ |A| .005 DIA

.460
3 PLACES

.620
4 PLACES

.515

.920
2 PLACES

.560
3 PLACES

.587 ± .005 DIA
5 HOLES
⊕ |A|B| .005 DIA

.747
3 PLACES

.925
3 PLACES

.094 ± .005 DIA
10 HOLES
⊕ |B| .005 DIA

.378 ± .005 DIA
⊕ |A| .005 DIA

1.080
2 PLACES

PART NO. 132D1287

MODULE, WARHEAD

D | 05606 | 132D1287

SEE NOTE 1

NOTES:

1. MATERIAL: FIBERBOARD PPP-F-320 TYPE SF
   (SOLID), CLASS-DOMESTIC, GRADE 350.

2. ANSI Y14.5-66 AND 304AB35 APPLY.

1.000
2 PLACES

.500
4 PLACES

.866
4 PLACES

2.40 ± .02 DIA

.062 THK STK

.55 ± .01 DIA
-A-

.10 ± .01 DIA
6 HOLES

⌖ | A | .01 DIA

PART NO. 196B7162

GENERAL ⊕ ELECTRIC
ARMAMENT SYSTEMS DEPT   LOC BURLINGTON, VT.

SPACER, DISC

SIZE | CODE IDENT NO
B | 05606 | 196B7162

SCALE 1/1 | SHEET 1 OF 1

CAT. A

REVISIONS

ZONE | LTR | DESCRIPTION | DATE | APPROVED

B | 196B7162 | REV

SEE NOTE 1

SIGNATURES
DRAWN
CHECKED
ISSUED
ENGRG
MATLS

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON
FRACTIONS DECIMALS ANGLES
±   ±   ±
ALL SURFACES 125/
MATL

NOTES:
1. MATERIAL: AL ALLOY: QQ-A-225/6
   (7075) TEMP T6.
2. ANSI Y14.5-66 AND 2000B APPLY.

2.78 ±.02 DIA

2.00 ±.02 DIA

.585 ±.010

2.490 ±.005 DIA

.30 ±.01

1.12 ±.02

3.37 ±.02

2.75 ±.03

.75 ±.03

2.375 - 12 UN - 2A

.04 ±.02

2.225 ±.020 DIA
2 PLACES

.500 - 13 UNC - 2B

PART NO. 167C1148

GENERAL ELECTRIC
ARMAMENT SYSTEM DEPT.   LOC. BURLINGTON, VT.

BASE, WARHEAD

SIZE | CODE IDENT NO.
C | 05606 | 167C1148

SCALE 1/1   SHEET 1 OF 1

SEE NOTE 1

CAT. A

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES—
TOLERANCES ON
2 PLACE DECIMALS ±
3 PLACE DECIMALS ±
ANGLES ±
FRACTIONS ±
MATERIAL—

ALL
SURF.
125√

167C1148

ADAPTER, FUZE

PART NO. 167C1247

NOTES:
1. MATERIAL: AL ALLOY: QQ-A-225/9
   (7075) TEMP T6.
2. ANSI Y14.5-66 AND STANDARDS APPLY.
3. MARK "167484-167C1247" PER DRAWING.

104

NOTES:

1. MATERIAL: FIBERBOARD PPP-F-320 TYPE SF (SOLID), CLASS-DOMESTIC, GRADE 350

2. ANSI Y14.5-66 AND 304A835 APPLY.

2.40 ± .02 DIA

.062 THK STK

.55 ± .01 DIA

PART NO. 196B7163

GENERAL ⊕ ELECTRIC
ARMAMENT SYSTEMS DEPT   LOC BURLINGTON, VT.

SPACER, DISC

SIZE	CODE IDENT NO.		
B	05606	196B7163	
SCALE 1/1		SHEET 1 OF 1	

CAT. A

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON
FRACTIONS   DECIMALS   ANGLES
±   ±   ±
ALL SURFACES   125 √
MAT'L.

SEE NOTE 1

REVISIONS
| ZONE | LTR | DESCRIPTION | DATE | APPROVED |

B 196B7163   1 OF 1

AEJZ   MRI

DIST TO

PH9883-F (13-73) PRINTED IN U.S.A.

NOTES:

1. MATERIAL: AL ALLOY: QQ-A-225/9 (7075) TEMP T6.

2. ANSI Y14.5-66 AND 304A635 APPLY.

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED

196B7161

.045 ±.010 R
2 PLACES

2.49 ±.01 DIA

.04 ±.02
2 PLACES

.50 ±.01

.64 ±.01

1.50 ±.02 DIA

.500-13UNC-2B

1.25 ±.01 DIA

PART NO. 196B7161

GENERAL ⊛ ELECTRIC
ARMAMENT SYSTEMS DEPT   LOC BURLINGTON, VT.

COVER, END, NOSE

SIZE	CODE IDENT NO	196B7161
B	0560G	

SCALE 1/1   SHEET 1 OF 1

CAT. A

SEE NOTE 1

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON:

NOTES

1. FINISH 125
2. SPECIFICATION MIL-W-13855 APPLIES.
3. MATERIAL: CARBON STEEL, TUBING QQ-T-830 COLD FINISHED TYPE 1010-1020.
4. ALL EXTERIOR CORNERS AND EDGES SHALL BE BROKEN .003 TO .015 UNLESS OTHERWISE SPECIFIED.
5. FINAL PROTECTIVE FINISH: FINISH 5.3.1.2 OR 5.3.2.2 OF MIL-STD-171.
6. CONCENTRICITY (TIR) WHEN NOT SPECIFIED IS THE SUM OF THE TOLERANCES OF ANY TWO CIRCULAR FEATURES DEPICTED ON THE SAME AXIS REGARDLESS OF THEIR FEATURE SIZE.
7. MARK '05606-135B5673' AND APPLICABLE DASH NUMBER PER 304A843.

PART NO.	-A- DIA	B DIA	C	MARKING
135B5673	504 DIA + .005	630 DIA - .005	.502 - .002	OMIT
135B5673-2	54 DIA + .02	625 DIA STK	.51 - .02	SEE NOTE 7
135B5673-3	54 DIA + .02	625 DIA STK	1.06 - .02	SEE NOTE 7
135B5673-4	54 DIA + .02	625 DIA STK	1.28 - .02	SEE NOTE 7
135B5763-5	54 DIA + .02	625 DIA STK	2.66 - .02	SEE NOTE 7

GENERAL ELECTRIC

MISSILE & ARMAMENT DEPT., BURLINGTON, VERMONT

SPACER, GEARSHAFT

CONTRACT NO. AF33(657)-8260

PART NO. 135B5673

HEREIN OF SPECIFIED — INCHES		
ANGLES ±		
FRACTIONS ± DECIMALS ±		
MATERIAL	SEE NOTE 3	
HEAT TREATMENT		
FINAL PROTECTIVE FINISH	SEE NOTE 5	

	SIGNATURES	DATE
DRAWN		
CHECKED		
ISSUED		
ENGRG		
MFG		

SIZE **B** | CODE IDENT NO 05606 | 135B5673

SCALE NONE | UNIT WT | SHEET 1 OF 1

024 1080 (11 84) PRINTED IN U.S.A.

NOTES:
1. ANSI Y14.5-66 AND 204A35 APPLY
2. MARK EACH PART OF THE MATCHED SET "105406-
1002002" AND MANUFACTURER'S PIECE NUMBER
FOLLOWING BY A HYPHEN AND SEQUENTIALLY
MATCHING SET NUMBER STARTING WITH ONE (1)
PER SERIAL STD LINE. THE WORD "SET" SHALL
PRECEDE THE PIECE NUMBER.

PARTIAL SECTION AA
ITEM 3 REMOVED FOR CLARITY

MATCHED PARTS, ORDER AND STOCK AS ONE PART

PART NO. 105D3601

NOSE, FUZE, MATCHED

D | 05606 | 105D3601

CAT "A"

INFORMATION FOR G. E. ONLY
NOT FOR MANUFACTURING
MAY NOT BE UP TO DATE

GENERAL ⊕ ELECTRIC

DEPT ... LOCATION

TITLE				CODE IDENT NO		PL 105 D 3601			SH NO	CONT ON SHEET	REV
... FUZE ... FED				05 ...							

DRAWING CODES	FOR GE USE ONLY	UNIT OF MEASURE CODES		REVISION CODES	
1 VENDOR ITEM - SPEC CONT DWG	4 SHORT FORM DWG	0 GRAMS 5 SETS		1 ITEM ADDED 4 IDENT NO. CHGD 6 EDIT CORRECTION	
2 VENDOR ITEM - SOURCE CONT DWG	5 INSEP ASSY	1 PIECES 6 OUNCES		2 ITEM DELETED 5 IDENT NO. AND	
3 ALTERED OR SELECTED PT	6 MTCHD PT	2 FEET 7 INCHES		3 QTY CHGD QTY CHGD	
	7 CUST PUBN PT	3 POUNDS 8 PINTS			
		4 GALLONS 9 OTHER			

ITEM NO.	ZONE	DWG CODE	IDENTIFICATION NO.	DESCRIPTION/ NOMENCLATURE	CODE IDENT NO	QTY	U/M	REV CODE
1			...D...A1	SECTION ... FUZE		1	1	
2			16...1115	SECTION , NOSE , FUZE		1	1	
3			MS...986-517	PIN , ...		4	1	
4			3803...-95-C-10-B	SCREW	56378	4	1	

SYM	REVISIONS			

MADE BY ...	APPROVALS	CONTRACT NO	PARTS LIST FOR
ISSUED ...14-...			105 D 3601
			CONT ON SHEET ... SH NO ...

NOTES:
1. MATERIAL: AL ALLOY QQ-A-225/6 OR QQ-A-200/11
2. ANSI Y14.5-66 AND SHADED APPLY

VIEW A-A

PARTIAL SECTION B-B

MACHINED AT ASSY
SEE DWG 49D2360

.125 REF

SECTION, MIDDLE, FUZE

PART NO 132D1241

| D | 05606 | 132D1241 |

SEE NOTE 1

SECTION, NOSE, FUZE

PART NO 167C1115

CODE IDENT NO C 05606

167C1115

SHEET 1 OF 1

CAT 'A'

NOTES:
1. MATERIAL: AL ALLOY, QQ-A-225/9
   OR QQ-A-250/11 (T6P3) TEMP T6.
2. MIL-STD Y14.5-66 AND SMALES APPLY.

.112 - 40 UNC-2B
.14 MIN DEEP
TAP DRILL
.20 MAX DEEP
A .030 DIA

MACHINED AT ASSY
SEE DWG 105D3601

.38±.01R
SPHER

.650 DIA ±.005

1.75±.01

.92±.01

1.370±.005

.133±.001

.125-40 UNC-2B
.30 MIN DEEP
TAP DRILL
.58 MAX DEEP
4 HOLES
K B .015 DIA

1.620±.002
DIA
A

.399

.042
±.001
4 PLACES

.493

.493

.399

.220±.001
4 PLACES

1.062±.005
DIA
A .010 DIA

.493

.399

.220±.001
4 PLACES

B

.493

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES—
TOLERANCES ON—
2 PLACE DECIMALS ±
3 PLACE DECIMALS ±
ANGLES ±
FRACTIONS ±
MATERIAL—

ALL
SURF
125√

SEE NOTE 1

2.75 IN. ROCKET
FUZE ASSY

ASSY NO 201F581

F 05606   201F581

CAT. A

112

ARMAMENT SYSTEMS	DEPT		BURLINGTON, VT			LOCATION

TITLE	2.75 IN. ROCKET	CODE IDENT NO.		SH NO	CONT ON SHEET	REV
	PL PT A	05 506	PL	1		

DRAWING CODES
1 VENDOR ITEM - SPEC CONT DWG
2 VENDOR ITEM - SOURCE CONT DWG
3 ALTERED OR SELECTED PT

FOR GE USE ONLY
4 SHORT FORM DWG
5 INSEP ASSY
6 MTCHD PT
7 CUST FURN PT

UNIT OF MEASURE CODES
0 GRAMS 5 SETS
1 PIECES 6 OUNCES
2 FEET 7 INCHES
3 POUNDS 8 PINTS
4 GALLONS 9 OTHER

REVISION CODES
1 ITEM ADDED 4 IDENT NO. CHGD 6 EDIT CORRECTION
2 ITEM DELETED 5 IDENT NO. AND
3 QTY CHGD QTY CHGD

ITEM NO.	ZONE	DWG CODE	IDENTIFICATION NO.	DESCRIPTION/ NOMENCLATURE	CODE IDENT NO	QTY	U/M	REV CODE
1		X6	105D3601	NOSE, FUZE, MATCHED		1	1	
2			132D1240	CAP, BASE, FUZE		1	1	
3		X5	132D1239	CORE, GENERATOR		1	1	
4			167C1116	HOUSING, CORE		1	1	
5			196B7164	RING, END		1	1	
6		X	196B7147	COIL ASSY, GEN		1	1	
7			196B7149	STRAP, GENERATOR		1	1	
8			163B5896	ROD, RETAINER		1	1	
9			196B7184	PIN, STRAIGHT		1	1	
10			MS35206-219	SCREW, MACH., PAN HD		2	1	
11			72BE267	BOARD, CIRCUIT		1	1	
12			SK5515T-D155	BOARD, CIRCUIT	12689	1	1	

SYM	REVISIONS				

MADE BY		APPROVALS	CONTRACT NO.	PARTS LIST FOR
			AEJE	201F581
ISSUED 3 14 73				CONT ON SHEET SH NO 1

TITLE 7.75 IN ROCKET ... A	CODE IDENT NO 05606	PL ... 81	SH NO 2	CONT ON SHEET	REV

DRAWING CODES	FOR GE USE ONLY	UNIT OF MEASURE CODES	REVISION CODES
1 VENDOR ITEM SPEC CONT DWG 2 VENDOR ITEM SOURCE CONT DWG 3 ALTERED OR SELECTED PT	4 SHORT FORM DWG 5 INSEP ASSY 6 MTCHD PT 7 CUST PURN PT	0 GRAMS 5 SETS 1 PIECES 6 OUNCES 2 FEET 7 INCHES 3 POUNDS 8 PINTS 4 GALLONS 9 OTHER	1 ITEM ADDED 4 IDENT NO CHGD 6 EDIT CORRECTION 2 ITEM DELETED 5 IDENT NO. AND 3 QTY CHGD QTY CHGD

ITEM NO	ZONE	DWG CODE	IDENTIFICATION NO.	DESCRIPTION/ NOMENCLATURE	CODE IDENT NO	QTY	U/M	REV CODE
12			12503024	ADAPTER, FUZE		1	1	
14			MS51963-21	SETSCREW		6	1	
15			MS51905-211	SCREW, MACH., PAN HD		1	1	
16			MS51963-20	SETSCREW		3	1	
17			19693155	HOUSING, OSCILLATOR		1	1	

SYM	REVISIONS				

MADE BY ...	APPROVALS	CONTRACT NO. AEJZ	PARTS LIST FOR ...F=81
ISSUED 3-14-75			CONT ON SHEET ... SH NO ...

2.75 IN. ROCKET
FUZE ASSY

ASSY NO. 201F529

201F529

GENERAL ● ELECTRIC

ARMAMENT SYSTEMS DEPT   BURLINGTON, VT   LOCATION

| TITLE 2.75 IN. ROCKET FUZE ASSEMBLY | CODE IDENT NO 05606 | PL 2011 529 | SH NO 1 | CONT ON SHEET 116 | REV |

DRAWING CODES	FOR GE USE ONLY	UNIT OF MEASURE CODES	REVISION CODES
1. VENDOR ITEM - SPEC CONT DWG	4 SHORT FORM DWG	0 GRAMS / 5 SETS	1 ITEM ADDED / 4 IDENT NO. CHGD / 6 EDIT CORRECTION
2. VENDOR ITEM - SOURCE CONT DWG	5 INSEP ASSY	1 PIECES / 6 OUNCES	2 ITEM DELETED / 5 IDENT NO. AND
3. ALTERED OR SELECTED PT	6 MTCHD PT / 7 CUST FURN PT	2 FEET / 7 INCHES / 3 POUNDS / 8 PINTS / 4 GALLONS / 9 OTHER	3 QTY CHGD / QTY CHGD

ITEM NO	ZONE	DWG CODE	IDENTIFICATION NO.	DESCRIPTION/ NOMENCLATURE	CODE IDENT NO	QTY	U/M	PL CODE
1			165 D 3001	NOSE, FUZE, MATCHED		1	1	
2			135 D 1240	CAP, BASE, FUZE		1	1	
3			13 D 1239	CORE, GENERATOR		1	1	
4			1 C 1116	HOUSING, CORE		1	1	
5			196 B 7164	RING, END		1	1	
6		X	196 B 1147	COIL ASSY, GEN		1	1	
7			196 B 1149	STRAP, GENERATOR		1	1	
8			163 B 5896	ROD, RETAINER		1	1	
9			196 B 7184	PIN, STRAIGHT		1	1	
10			MS35206-211	SCREW, MACH., PAN HD		1	1	
11			MS35206-219	SCREW, MACH., PAN HD		2	1	
12			196 C 7	BOARD, CIRCUIT		1	1	
13			SK56157-D155	BOARD, CIRCUIT	13608	1	1	

SYM	REVISIONS					

MADE BY	APPROVALS	CONTRACT NO	PARTS LIST FOR
ISSUED 3-14-72		NEJE	CONT ON SHEET SH NO 1

2.75 IN. SIGNATURE WARHEAD ASSY

ASSY NO 2O1F797

CLEAR PLASTIC TUBE REF

AE-ACCELERATION SWITCH REF

THREADED ROD REF

WASHER REF

LOCK WASHER REF

NUT REF

SECTION A-A
3 PLACES

3-FLASH BULB REF

THREADED ROD REF

3-S RUBBER GROMMET REF

SECTION B-B
3 PLACES

3-CAPACITOR REF

4.8 VOLT BATTERY REF

3-FLASH BULB REF

THREADED ROD REF

GENERAL ELECTRIC

F 05606 2O1F797

CAT. A

ARMAMENT SYSTEMS DEPT   BURLINGTON, VT   LOCATION

| TITLE 2.75 IN. SIGNATURE WARHEAD ASSY | CODE IDENT NO. 05606 | PL 201F797 | SH NO 1 | CONT ON SHEET FIN | REV |

DRAWING CODES	FOR OE USE ONLY	UNIT OF MEASURE CODES		REVISION CODES	
1. VENDOR ITEM · SPEC CONT DWG	4. SHORT FORM DWG	0 GRAMS	5. SETS	1 ITEM ADDED	4. IDENT NO. CHGD 6 EDIT CORRECTION
2. VENDOR ITEM · SOURCE CONT DWG	5. INSEP ASSY	1. PIECES	6. OUNCES	2. ITEM DELETED	5. IDENT NO. AND
	6. MTCHD PT	2. FEET	7. INCHES		QTY CHGD
3. ALTERED OR SELECTED PT	7. CUST PUBN PT	3. POUNDS	8 PINTS	3. QTY CHGD	
		4 GALLONS	9 OTHER		

ITEM NO.	ZONE	DWG CODE	IDENTIFICATION NO.	DESCRIPTION/ NOMENCLATURE	CODE IDENT NO.	QTY	U/M	REV CODE
1			201F581	2.75 IN. ROCKET FUZE ASSY		1	1	
2			132D1287	MODULE, WARHEAD		3	1	
3			135B5673-4	SPACER		6	1	
4			196B7162	SPACER, DISC		4	1	
5			167C1148	BASE, WARHEAD		1	1	

INFORMATION ...
NOT FOR ...
MAY NOT BE ...

SYM	REVISIONS			

MADE BY	APPROVALS	CONTRACT NO.	PARTS LIST FOR
ISSUED 3-21-75		AEJZ	201F797 CONT ON SHEET FIN SH NO 1